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Document Subject:

TRANSMITTAL OF THE FINAL TECHNICAL MEMORANDUM NO. 1, MONITORED NATURAL ATTENUATION OF IHSS 118.1, REV. 1 - JEL-130-98

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July 28, 1998

Please find enclosed the "**Final Technical Memorandum No. 1, Monitored Natural Attenuation of IHSS 118.1, Revision 1**" for submittal to the DOE, the EPA, and the CDPHE. Included are (4) copies for Kaiser-Hill, (3) copies for the DOE, (2) copies for the EPA, and (2) copies for the CDPHE. The document has been revised based on regulator comments and the response to these comments is also attached. A draft submittal letter for transmission of the document to the Department of Energy's Rocky Flats Field Office has been attached for your convenience.

If you have any questions please contact Craig Cowdery at 966-2055.

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ER Records

ADMIN RECORD





FINAL TECHNICAL MEMORANDUM NO. 1

MONITORED NATURAL ATTENUATION OF IHSS 118.1

RF/RMRS-97-094.UN



July 1998
Revision 1
ADMIN RECORD

RF/RMRS-97-094.UN

**FINAL
TECHNICAL MEMORANDUM NO.1
MONITORED NATURAL ATTENUATION OF
IHSS 118.1**

July 1998

FINAL TECHNICAL MEMORANDUM NO.1
MONITORED NATURAL ATTENUATION OF IHSS 118.1

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ACRONYMS

µg/kg	micrograms per kilogram
µg/L	micrograms per liter
AHA	Activity Hazard Analysis
ALF	Action Level Framework
APEN	Air Pollution Emissions Notification
ARAR	Applicable Relevant and Appropriate Requirement
bgs	below ground surface
CERCLA	Comprehensive Environmental Resource, Compensation, and Liability Act
CFR	Code of Federal Regulations
DNAPL	dense nonaqueous phase liquid
DOE	Department of Energy
EPA	Environmental Protection Agency
ER	Environmental Restoration
FO	Field Operations
g/min	grams per minute
gpm	gallons per minute
HASP	Health and Safety Plan
HPGe	high purity germanium
HRR	<i>Historical Release Report</i>
IDM	Investigation Derived Material
IGD	<i>Rocky Flats Cleanup Agreement Implementation Guidance Document</i>
IMP	<i>Integrated Monitoring Plan</i>
IHSS	Individual Hazardous Substance Site
LNAPL	light nonaqueous phase liquid
mg/kg	milligram per kilogram
NEPA	National Environmental Policy Act
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
OU	Operable Unit
PARCC	Precision, accuracy, reproducibility, completeness, and comparability
PPE	personal protective equipment
pCi/g	picocuries per gram
QAPD	Quality Assurance Project Description
RAAMP	Radioactive Ambient Air Monitoring Program
RCRA	Resource Conservation and Recovery Act
RFCA	<i>Rocky Flats Cleanup Agreement</i>
RFETS	Rocky Flats Environmental Technology Site
RFFO	Rocky Flats Field Office
RFI	RCRA Facility Investigation
RI	Remedial Investigation
RMRS	Rocky Mountain Remediation Services, L.L.C.
SAP	Sampling and Analysis Plan
Site	Rocky Flats Environmental Technology Site
VOC	volatile organic compound

EXECUTIVE SUMMARY

This technical memorandum outlines the rationale for the selection of monitored natural attenuation as a near-term measure to address potential risks posed by releases of carbon tetrachloride at Industrial Hazardous Substance Site (IHSS) 118.1. IHSS 118.1 is a former underground storage tank that stored carbon tetrachloride for process use. Inadvertent releases associated with filling and failure of the tank system resulted in the loss of an unknown quantity of carbon tetrachloride. In addition to IHSS 118.1, it is likely that there are other sources of carbon tetrachloride and other volatile organic compound contamination in the industrial area. Over the next several years, characterization of the industrial area will be conducted to evaluate these sources and determine an appropriate remedial action for the entire industrial area.

Currently, contaminants from IHSS 118.1 do not appear to pose a near-term risk. Groundwater in the vicinity of IHSS 118.1 is not being utilized. Based on contaminant concentrations and groundwater flow in the area of IHSS 118.1, no contamination is entering surface water. Furthermore, the mass flow rate or flux of carbon tetrachloride decreases considerably from IHSS 118.1 to downgradient areas and is not detectable in downstream surface water.

Natural attenuation processes include "a variety of physical, chemical, and biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume or concentration of contaminants in soil or groundwater" (EPA, 1997). Monitored natural attenuation was selected to address IHSS 118.1 for the following reasons. First of all it is unlikely that any proven in situ treatment technology could recover sufficient amounts of the subsurface carbon tetrachloride to significantly reduce aqueous concentrations of carbon tetrachloride downgradient of the IHSS. This is based on the limitation of proven in situ remediation technologies, limited accessibility to the contamination due to plant infrastructure, and the complex distribution of carbon tetrachloride (a dense nonaqueous phase liquid [DNAPL]) in the low permeability soils present at the site. Furthermore, IHSS 118.1 does not appear to be a near-term risk since surface water has not been impacted and IHSS 118.1 will be addressed along with a number of other sources as part of the Industrial Area plume evaluation. Finally, natural attenuation does appear to be effectively controlling the migration of contaminants through a combination of physical, chemical, and biological processes.

The proposed action includes the installation and sampling of six groundwater monitoring wells in the vicinity of IHSS 118.1 and additional sampling of existing IHSS 118.1 wells. Sampling and analysis will be performed to evaluate that natural attenuation processes are limiting contaminant migration over time. Key indicators will be evaluated in source area wells, as well as, in wells located upgradient and downgradient from the source. Sampling and reporting activities will be integrated with current activities under the Integrated Monitoring Plan (IMP).

Although promising, there are uncertainties as to effectiveness of natural attenuation. If natural attenuation does not provide long-term risk reduction, then additional action such as source removal may be needed once IHSS 118.1 becomes accessible (i.e., key tanks and utilities are no longer needed). Any final action will ultimately be based on an evaluation of natural attenuation and a better understanding of interaction between IHSS 118.1 and contamination in the Industrial Area of Rocky Flats Environmental Technology Site (the Site).

1.0 INTRODUCTION

IHSS 118.1, Multiple Solvent Spills West of Building 730, is located within the Industrial Area Operable Unit (OU) and was previously designated as a part of the former OU 8. IHSS 118.1 is ranked number eight (of over 200 sites) in the Environmental Restoration (ER) Ranking (Attachment 4 to the *Rocky Flats Environmental Cleanup Agreement* [RFCA], [DOE, 1996a]) and the groundwater plume associated with IHSS 118.1 is ranked eighteenth. IHSS 118.1 is the result of releases that occurred in the 1960s, 1970s, and early 1980s associated with the operation of one 5,000-gallon underground carbon tetrachloride storage tank located adjacent to Building 730. Over this time period, an unknown quantity of carbon tetrachloride was released into the environment. Remedial investigation results indicate that carbon tetrachloride migrated below the water table and accumulated in the bedrock depression encompassing a group of subsurface process waste tanks (Tanks T-9 and T-10) located adjacent to the former carbon tetrachloride tank. The carbon tetrachloride partially displaced the groundwater to create a zone of dense non-aqueous phase liquid (DNAPL) at the base of the Tanks T-9 and T-10. Because the DNAPL zone is situated in a heterogeneous fill material with mixed permeabilities underlain by a low permeability bedrock, movement of DNAPL is constrained both on the inside and outside of this zone.

Based on water analytical results and an evaluation of groundwater flow, there does not appear to be a near-term risk posed by IHSS 118.1. The groundwater in the vicinity of IHSS 118.1 is not being utilized. The concentrations of contaminants in the 700 area footing drains are low or non-detectable, and carbon tetrachloride has not been detected in the nearest downstream surface water location. Furthermore, the concentration and total mass of contaminants decreases considerably downgradient from IHSS 118.1 to non-detectable levels in downstream surface water.

Based on the results of an alternative analysis, the best approach to address near-term risk is to monitor natural attenuation. Natural attenuation includes "a variety of physical, chemical, and biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume or concentration of contaminants in soil or groundwater" (EPA, 1997). Monitored natural attenuation was selected because more aggressive remedial technologies were not feasible due to the presence of utilities, Tanks T-9/T-10, and other physical impediments to implementation. In addition, many of these technologies would have left residual DNAPL that would effectively sustain contaminant concentrations for decades. Although excavation was determined to be the most effective technology; it cannot be implemented until building closures occur. Monitored natural attenuation offers advantages over no interim action since it will provide additional monitoring and evaluate whether natural processes are limiting contaminant migration as the remedial investigation data suggested. An alternative analysis is presented in Appendix A of this document.

A technical memorandum is being submitted instead of an Interim Measure/Interim Remedial Action Plan because the project approach is to monitor existing natural remedial processes as opposed to implementing an interim remedial action. This technical memorandum serves to document a remedial strategy that will be integrated into the current monitoring program conducted under the *Integrated Monitoring Plan* (IMP) (Kaiser-Hill, 1997), and therefore, is not a decision document. The technical memorandum is divided into the following sections:

Executive Summary

1.0 Introduction - This section consists of a general overview of the technical memorandum and describes how the document is organized.

2.0 Project Description - This section presents a historical background of IHSS 118.1, a conceptual model, and the results of past remedial activities.

3.0 Project Approach - This section details the objectives of monitored natural attenuation and how it will be implemented.

4.0 Environmental Issues - This section evaluates issues and impacts associated with monitored natural attenuation.

5.0 Implementation Schedule - This section contains a generalized schedule of how the work will be accomplished.

6.0 References

Appendix A - This appendix presents a two-part alternative analysis, a broad-based screen followed by a more detailed comparison of three alternatives.

Appendix B - This appendix describes the calculation of the mass flux and mass flow rate of carbon tetrachloride at IHSS 118.1.

2.0 PROJECT DESCRIPTION

This section provides a brief project background and data summary along with a description of the hydrogeologic setting and existing site conditions. More detailed information can be found in the *Sampling and Analysis Plan for the Pre-Remedial Investigation of IHSS 118.1* (RMRS, 1997a); *Final Pre-Remedial Investigation of IHSS 118.1 Data Summary Report* (RMRS, 1997b); *Hydrogeologic Characterization Report for the Rocky Flats Environmental Technology Site* (EG&G, 1995a); *Phase I Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI)/Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Remedial Investigation (RI) Work Plan for Operable Unit 8, 700 Area* (DOE 1994a); *Technical Memorandum 1, Investigations of Foundation Drains and Other Data Compilations, Addendum to the Operable Unit 8 Work Plan* (DOE, 1994b), and; the *Historical Release Report* (HRR) (DOE, 1992).

2.1 BACKGROUND

The location of IHSS 118.1, Multiple Solvent Spills West of Building 730, is shown on Figure 2-1. The IHSS is associated with a 5,000-gallon underground steel storage tank and concrete containment structure (See Figure 2-2). The tank previously stored unused carbon tetrachloride and was located adjacent to the west side of Building 730 and just north of Building 776 (DOE, 1992).

There have been multiple releases from the tank and associated piping throughout its period of operation from approximately 1963 to 1981. In the 1970s, tank overflows occurred during filling operations. The HRR also states that prior to 1970 a spill of 100 to 200 gallons of trichloroethene occurred north of Building 776. Due to conflicting information, it is postulated in the HRR that the spill was actually carbon tetrachloride. On February 26, 1976, it was discovered that corroded piping (or possibly a valve) was leaking carbon tetrachloride into the tank's sump pit. On June 18, 1981, the tank inlet failed, releasing carbon tetrachloride into the sump. The tank was subsequently removed (DOE, 1992).

The tank was configured with its long axis running north to south. A concrete containment structure (valve vault) that housed the pump and valves was at the south end of the tank (see Figures 2-2 and 2-3). It is believed that remnants of the concrete containment structure are still in place. The east side of the containment structure was approximately 10 feet west of the exposed portion of the Building 730 pump house (DOE, 1992). The area is relatively flat and includes both paved and unpaved surfaces. Four feet east of the former carbon tetrachloride storage tank is a group of four process waste tanks referred to as tank groups T-9 and T-10. These tanks were part of the old process waste system. Tank T-9 consists of two-22,500 gallon process waste underground storage tanks. T-10 consists of two-4,500 gallon concrete underground tanks. Both sets of tanks were installed in 1955. T-9 was converted in 1984 to a plenum deluge catch tank for Building 776 and remains in use. T-10 has been emptied, rinsed, sampled and foamed (DOE, 1996b). No releases from either set of tanks have been documented (DOE, 1992).

There are numerous utilities and structures underground and overhead in the IHSS 118.1 area. Figure 2-3 presents a cut away view showing some of the utilities and the former tank location. Additional utilities are present that are not shown on this figure. These utilities include vitreous clay sanitary sewer lines, electrical lines, tunnels between buildings, and process waste tanks. Information from excavations in other areas and conversations with workers indicate that most of the buried utilities were backfilled using previously excavated native materials (DOE, 1994a). As noted by the pre-remedial investigation sampling and analysis plan (RMRS, 1997a), there is a potential for contamination in the groundwater to migrate along the underground utility corridors in this area. The most likely utility pathway is a process waste line leaving the T-9 and T-10 tank system and running eastward at a depth of 6 to 8 feet below ground surface.

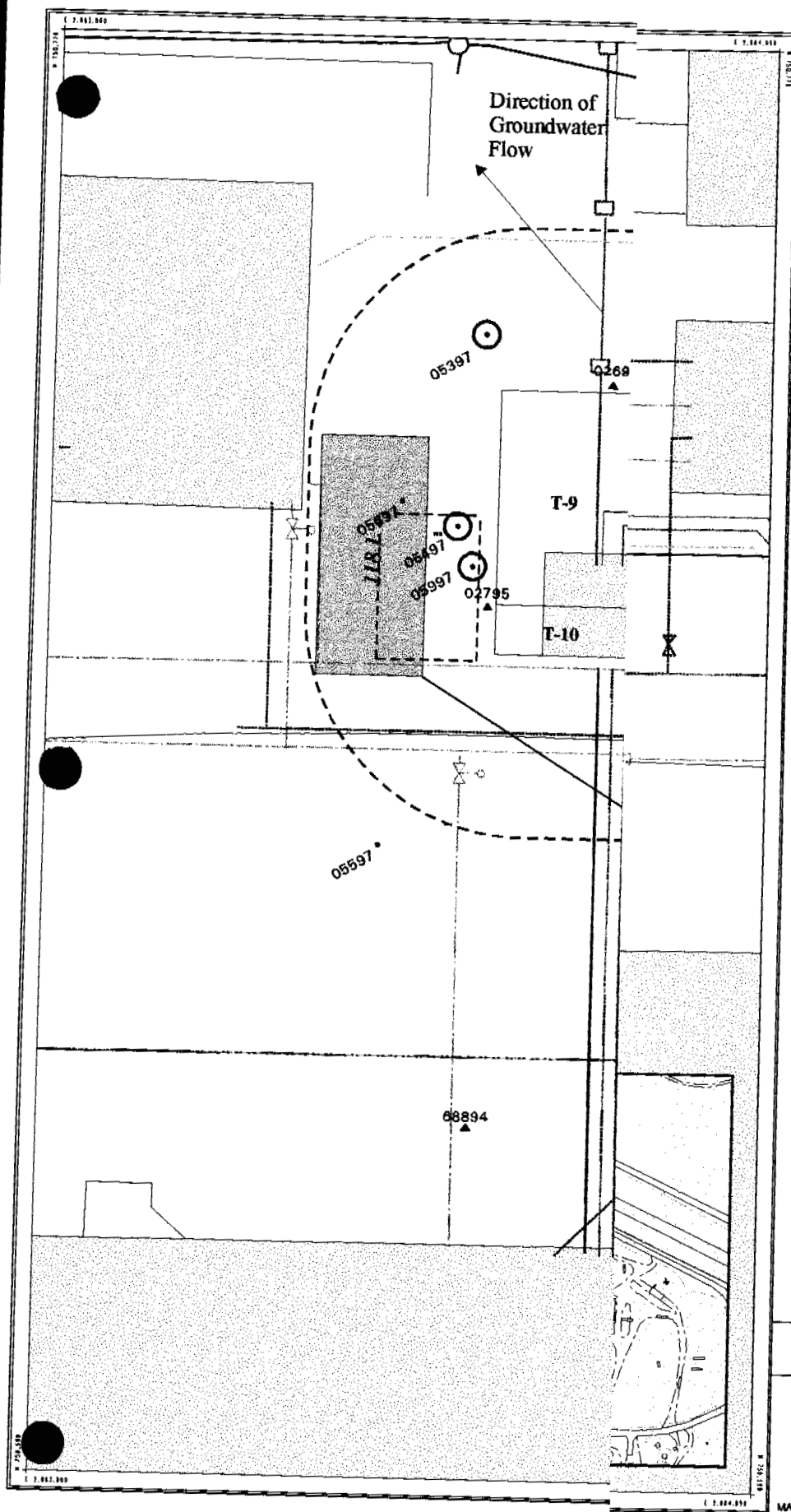


Figure 2-1

IHSS 118.1 Location Map
Boreholes, Wells & Tank Locations
 (Including Utilities for Area
 except Alarms & Communications)

EXPLANATION

- Geoprobe Boreholes & Wells (FY97)
- ▲ Pre-existing Boreholes
- Observed Free-Phase NAPL
- Process Waste Tanks (IHSS 132)
- IHSS 118.1
- ∇ Former Location Carbon Tetrachloride Tank

Utility Features

- ⚡ Electrical (Above & below ground)
- ⚡ Natural Gas
- ⚡ Process Waste disconnected E. of IHSS 132
- ⚡ Sanitary Sewer disconnected E. of IHSS 132
- ⚡ Storm Drains
- ⚡ Water

Standard Map Features

- ▭ Buildings and other structures
- Fences and other barriers
- Paved roads
- Dirt roads



Scale = 1 : 240
 1 inch represents 20 feet



State Plane Coordinates Projection
 Colorado Central Zone
 Datum: NAD27

U.S. Department of Energy
 Rocky Flats Environmental Technology Site

Rocky Mountain
Remediation Services, L.L.C.
 Geographic Information Systems Group
 Rocky Flats Environmental Technology Site
 P.O. Box 464
 Golden, CO 80402-0464

MAP ID: 98-0016

March 10, 1998

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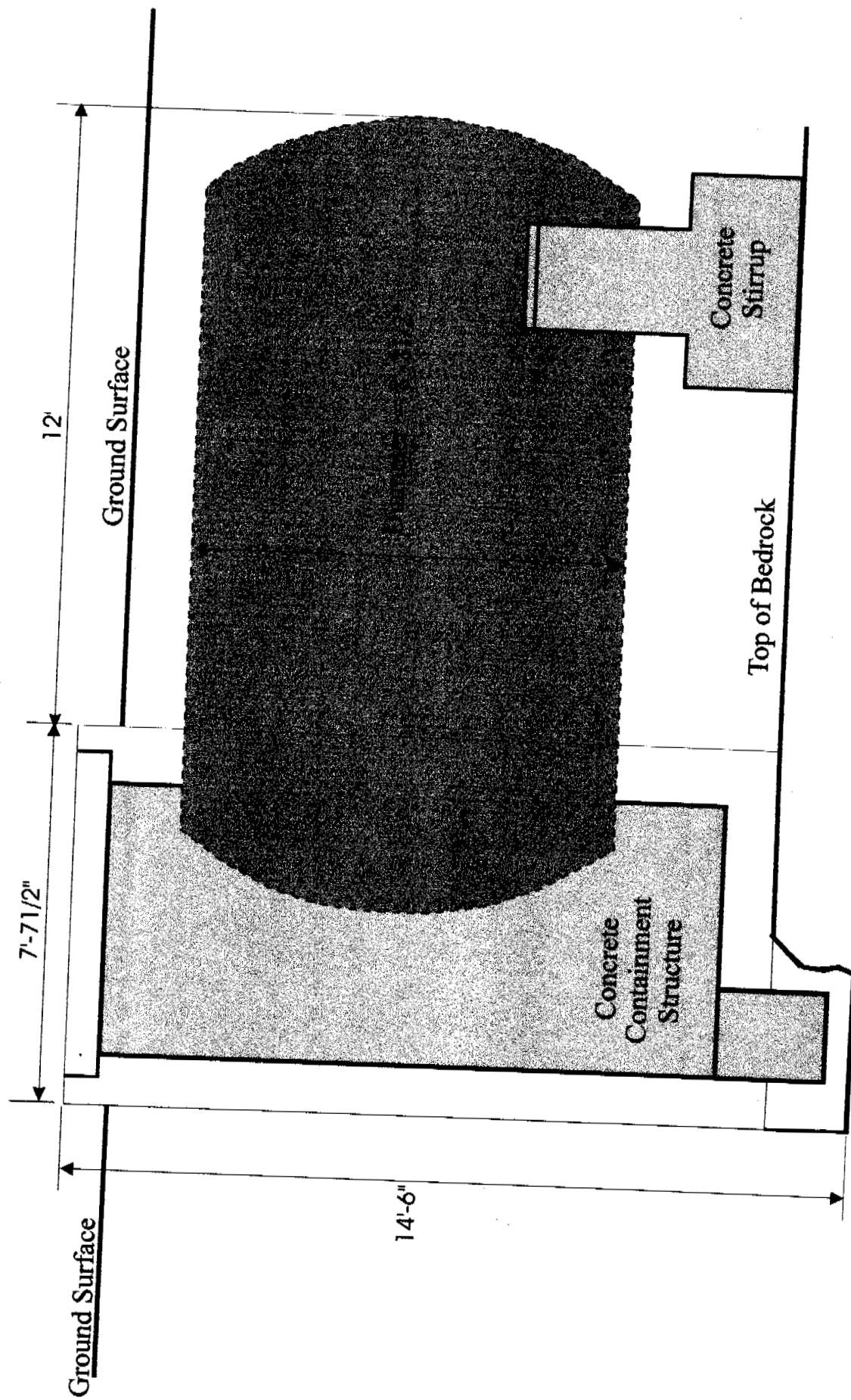


Figure 2-2 Cross Section of Former Carbon Tetrachloride Tank
(Based on Engineering Drawing)

Additionally, a vitreous clay sanitary sewer line is present 20 feet north of the carbon tetrachloride spill at a depth of 6 to 8 feet below ground surface. While the utility corridors in this area are possible preferential pathways for migration of the dissolved-phase groundwater plume, nonaqueous carbon tetrachloride is not likely migrating via these conduits because it is confined at a depth of approximately 20 feet below ground surface due a greater density than water.

2.2 HYDROGEOLOGIC SETTING

The upper strata in the vicinity of IHSS 118.1 is comprised of 8 to 14 feet of surficial materials immediately underlain by weathered bedrock of the Arapahoe Formation. The surficial materials consist of artificial fill composed of reworked Rocky Flats Alluvium with some undisturbed Rocky Flats Alluvium. The alluvium is primarily composed of clay with interspersed unconsolidated gravels and sands (RMRS, 1997b). The weathered bedrock lithology in most locations is claystone or siltstone; however, Arapahoe Formation sandstones (i.e., Arapahoe No. 1 Sandstone) have been observed east of the IHSS near the Solar Evaporation Ponds (EG&G, 1995a).

Groundwater flow in the IHSS 118.1 area is generally to the north and northwest towards the North Walnut Creek drainage, which is consistent with the potentiometric surface (i.e., water table) of groundwater in the surficial deposits (EG&G, 1995a). Figure 2-4 shows the water table contours based on recent data from the pre-remedial investigation wells, RCRA monitoring wells, and foundation drain drawings. Building 771 to the north, Building 774 to the northeast, and Building 776 to the south have below grade construction 20 to 30 feet below ground surface (RMRS, 1997a). These structural features, coupled with the foundation drains that de-water the soils surrounding these buildings likely influence the local groundwater flow. Due to its proximity to IHSS 118.1, the Building 771 foundation drain may exert the strongest influence on flow. Based on information presented in the geologic characterization report (EG&G, 1995b), it is assumed that the top of bedrock surface, prior to the construction of Buildings 771 and 774, sloped to the north away from IHSS 118.1 and was approximately 10 to 15 feet below ground surface. Excavation could have either increased the slope of the bedrock surface, or created a depression in the bedrock next to the building.

The previous field investigation of Tanks T-9 and T-10, located immediately to the east of IHSS 118.1, provides additional relevant information with respect to the hydrogeologic and subsurface topography for IHSS 118.1. The boreholes located in the T-9 and T-10 area encountered the bedrock surface 10 feet below where it was anticipated (i.e., approximately 22 feet below ground surface). Based on these observations, it is assumed that installation of Tanks T-9 and T-10 created a localized excavation into the bedrock surface. According to the HRR (DOE, 1992), the bottoms of these tanks are approximately 26 feet below ground surface; however, a review of engineering drawings for the tanks indicates that the depth is shallower (i.e., 22 feet below ground surface). The HRR (DOE, 1992) indicates that the carbon tetrachloride tank and associated concrete containment structure were 9.1 and 10.25 feet below ground surface, respectively. Review of engineering drawings for the carbon tetrachloride tank indicates that this reported depth is accurate. The excavation associated with Tanks T-9 and T-10 is significantly deeper than for the carbon tetrachloride tank.

As indicated in Section 2.3, one of the objectives of the pre-remedial investigation sampling was to refine the interpretation of the bedrock surface in the area to assist in determining the size of the T-9/T-10 tank excavation. Depth to bedrock was interpreted for each borehole; however, the bedrock contact was difficult to determine due to reworked bedrock claystone in the fill material and poor recovery. The bedrock contacts selected for each location are consistent with a steep-sided excavation into bedrock. Table 2-1 provides the depth to bedrock for each location.

Table 2-1. Total Depth, Depth To Bedrock, And Depth To Groundwater For Each Borehole.

Location	Total Depth (in feet)	Depth to Bedrock (in feet)	Well (yes/no)	Depth to Groundwater (feet bgs*)
05197	28.0	13.6	Yes	7.49
05297	27.0	20.8	No	-
05397	27.0	21.5	Yes	8.50
05497	27.0	22.1	Yes	6.52
05597	12.0	8.0	No	-
05697	22.0	18.8	Yes	6.85
05797	12.0	5.8	No	-
05897	24.0	21.4	Yes	6.75
05997	30.0	24.0	Yes	7.37

*feet below ground surface (bgs) - measured depth in feet from the ground surface to the groundwater table

While the areal extent of the depression was not confirmed on the west or north sides, with the exception of the former carbon tetrachloride tank to the west, there are no other known subsurface structures or excavations immediately to the north or west. The building immediately west of the excavation, Building 701, is built on a concrete slab. Therefore, the excavation is believed to be a closed depression into the bedrock surface which may be slightly stepped down on the west side, and steep-sided on the other three sides. The bedrock sides and bottom of the depression consist of the Arapahoe Formation claystone. Groundwater is present 6 to 9 feet below the ground surface (Table 2-1).

2.3 REMEDIAL INVESTIGATIONS

In addition to the historical release information summarized above, data are available for interpretation of the nature and extent of contamination associated with IHSS 118.1. These data sources are provided from the OU 8 RFI/RI and the OU 9 RFI/RI intrusive investigation of Tanks T-9 and T-10 located adjacent to IHSS 118.1. These investigations are summarized in Section 2.3.1. Figure 2-1 illustrates the locations and types of samples collected during these investigations.

Specifically for this IHSS, sampling and analysis was conducted in September of 1997 to determine the nature and extent of the contamination. The results of the pre-remedial investigation are summarized in Section 2.3.2. The pre-remedial investigation sampling locations are also illustrated on Figure 2-1.

2.3.1 Industrial Area Investigations

The OU 8 RFI/RI included the identification and sampling of building foundation drains and storm sewers which could potentially be impacted by contaminant releases at IHSS 118.1 and the other OU 8 IHSSs. Additionally, surface radiological and soil-gas surveys were conducted as part of the OU 8 RFI/RI in the IHSS 118.1 vicinity. Surface soil, subsurface soil, and groundwater sampling were conducted in support of the OU 9, Original Process Waste Lines, RFI/RI, including tank systems T-9 and T-10 located immediately east of IHSS 118.1 (see Figure 2-1). A total of four boreholes (02695, 02795, 02895, and 02995) were completed around Tanks T-9/T-10 for this program. The sampling locations for

the OU 8 and OU 9 previous investigations are shown on Figure 2-1 and the results are discussed in the following paragraphs.

Foundation Drains

Utility drawings do not show any storm sewers near IHSS 118.1. Additionally, foundation drains were not identified in Building 701 which is immediately west of IHSS 118.1. Foundation drains were identified in Buildings 771 and 774 (Figure 2-1). These buildings are located to the north and northeast of IHSS 118.1, respectively. As described in Section 2.2, the direction of groundwater flow is believed to be to the north/northwest. As a result, there is a potential for those foundation drains to be impacted by the carbon tetrachloride releases at IHSS 118.1. Samples collected in 1993 from FD-771-1 indicate carbon tetrachloride was detected in the foundation drain water at 43 micrograms per liter ($\mu\text{g/L}$) which is in the groundwater flow direction. Volatile Organic Compounds (VOCs) were not detected in foundation drain samples collected in 1993 from FD-774-1, FD-774-2, and FD-774-3 which are located to the north/northeast of Building 774. A detailed discussion of the foundation drains is provided in the OU8 Technical Memorandum 1 (DOE, 1994b).

Radiological Survey

Radiological surveys include a High Purity Germanium (HPGe) measurement within IHSS 118.1. The survey results indicate that americium-241 (0.2 picocuries per gram [pCi/g]) and plutonium-239 (1.3 pCi/g) are above background in the surface soil but well below the Rocky Flats Cleanup Agreement (RFCA) Tier II Surface Soil Action Levels of 38 and 252 pCi/g for americium-241 and plutonium-239, respectively.

Soil-Gas Survey

The soil-gas survey was conducted on a 20-foot grid at an approximate depth of 5 feet below ground surface. The survey included seven soil gas samples within and in the immediate vicinity of IHSS 118.1 and an additional five soil-gas survey locations to the north and east of IHSS 118.1. Carbon tetrachloride was detected in five of the seven soil-gas survey locations for IHSS 118.1 at concentrations ranging from 1.2 to 210 micrograms per liter ($\mu\text{g/L}$). Additionally, carbon tetrachloride was detected at 3.2 $\mu\text{g/L}$ in the sample collected from the east side of IHSS 118.1 (soil-gas location SG002494). These data along with other compounds detected in the soil-gas samples are also indicated in Table 2-2.

Surface Soil Samples

Surface soil and subsurface soil samples were collected at borehole locations 02695, 02795, 02895, and 02995 adjacent to Tanks 9 and 10. Analytical results from surface soil samples indicate that carbon tetrachloride was not detected. The laboratory results for organic compounds detected in surface soil samples are summarized in Table 2-3. Radionuclide results for the surface soil samples indicate that americium-241 and plutonium-239/-240 were above background but below RFCA Tier II Surface Soil Action Levels presented in Table 2-4.

Table 2-2. OU 8 IHSS 118.1 RF/RI Soil-Gas Sample Results ($\mu\text{g/L}$).

Compound	SG000194	SG000294	SG000394	SG000494	SG000594	SG000694	SG000794	SG002494	SG002594	SG002694	SG002794	SG002894
Acetone	ND	ND	ND	ND	2.1	ND	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	23	2.2	3.4	24	3.2	ND	ND	ND	ND
Chloromethane	ND	ND	ND	ND	ND	ND	38	ND	ND	ND	ND	ND
Carbon Tetrachloride	1.2	ND	ND	210	18	25	ND	ND	ND	ND	ND	ND
Dichlorodifluoro- methane	ND	ND	ND	ND	ND	ND	2.0	ND	ND	ND	ND	ND
1,1-Dichloroethene	ND	ND	ND	ND	1.3	ND	1.6	ND	ND	ND	ND	ND
Cis-1,2-Dichloroethene	ND	ND	ND	ND	1.1	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	2.0	ND	ND	1.8	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	8.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	ND	ND	1.2	ND	ND	ND	ND	ND
Trichlorofluoromethane	ND	ND	3.6	ND	12	26	18	ND	ND	ND	ND	ND

ND = Not Detected

Table 2-3. Organic Compounds Detected in OU 9 RFI/RI Surface And Subsurface Soils (mg/kg) and Corresponding RFCA Action Levels.

Compound Detected													
		Benzo (a) anthracene	Benzo (a) pyrene	Benzo (b) fluoranthene	Carbon Tetra-chloride	Chloro-form	Chrysene	Fluor-anthene	Hexa-chloro-ethane	Phen-anthrene	Pyrene	2-Buta-none	4-Methyl-2-pentanone
	RFCA Tier II Surface Soil Action Level (mg/kg):	7.84	0.784	7.84	44	938	784	81,800	409	—	61,300	>1E06	164,000
	RFCA Tier I Subsurface Soil Action Level (mg/kg):	71.9	317	177	11	152	—	130,000	36.4	—	134,000	<1E06	229
Sample Results													
02695	0-6 in	ND	ND	ND	<0.012	ND	ND	0.440	ND	ND	0.460	ND	ND
	6.3- 8.3 ft. *	ND	ND	ND	0.005J	ND	ND	ND	ND	ND	ND	ND	ND
	22.0-22.8 ft. *	ND	ND	ND	81,000	3,800	ND	ND	ND	ND	ND	ND	ND
02795	0-6 in.	0.410	0.430	0.510	<0.011	ND	0.430	0.870	ND	0.490	0.890	ND	ND
	4.6- 5.1 ft. *	ND	ND	ND	0.034	ND	ND	0.044J	ND	ND	ND	ND	ND
02895	0-6 in. **	0.530	0.580	0.570	<0.011	ND	0.610	1.40	ND	0.860	1.40	ND	ND
	4.6-6.9 ft. *	ND	ND	ND	<0.012	ND	ND	ND	ND	ND	ND	ND	ND
	22.0-22.5 ft. *	ND	ND	ND	25,000	ND	ND	ND	ND	ND	ND	0.029	0.043
02995	0-6 in	ND	ND	ND	<0.011	ND	ND	ND	3.30	ND	ND	ND	ND
	8.0-9.4 ft. *	ND	ND	ND	0.017	ND	ND	0.590	ND	0.430	0.600	ND	ND
	26.0-27.8 ft. *	ND	ND	ND	9,800	ND	ND	ND	ND	ND	ND	ND	ND

* Sample depth determined to be below the water table following recovery of groundwater in borehole.

** Analytical results

* Sample depth determined to be below the water table following recovery of groundwater in borehole.

** Analytical results of duplicate sample collected at this location, real samples results were less than detection limits.
ND Not detected

Table 2-4. Radionuclides Detected Above Background In OU 9 RFI/RI Surface and Subsurface Soils (pCi/g) and Corresponding RFCA Action Levels.

		Radionuclides Detected	
		Am-241	Pu-239/240
RFCA Tier II Subsurface Soil Action Levels (pCi/g):		38	252
Location	Depth	Sample Results	
02695	0-6 in	0.064	0.429
	6.3- 8.3 ft. *	NA	—
	22.0-22.8 ft *	—	—
02795	0-6 in.	0.185	2.038
	4.6- 5.1 ft. *	—	—
02895	0-6 in. **	1.602	7.386
	4.6-6.9 ft. *	—	—
	22.0-22.5 ft *	—	—
02995	0-6 in	—	—
	8.0-9.4 ft. *	—	—
	26.0-27.8 ft *	—	—

* Sample depth determined to be below the water table following recovery of groundwater in borehole.

** Duplicate sample.

NA = Not analyzed.

— = Result is below background concentrations.

Subsurface Soil Samples

Analytical results for carbon tetrachloride in subsurface soil samples collected just beneath the water table at locations 02695, 02795, 02895, and 02995 were 0.005 (estimated), 0.034, <0.012, and 0.017 milligrams per kilogram (mg/kg), respectively. Samples near the bedrock surface were obtained from three of the four boreholes. A bedrock sample could not be taken from Borehole 02795 because the core could not be recovered. Analytical results from the three samples collected from the bedrock surface indicated the presence of carbon tetrachloride in the percent range (9 to 16%). Table 2-3 presents the laboratory results for organic compounds detected in the subsurface soil samples. Concentrations of carbon tetrachloride in subsurface soil from the three borings exceeded the RFCA Tier I Subsurface Soil Action Level of 11 mg/kg. Chloroform concentrations in Boring 02695 also exceeded the respective action level of 152 mg/kg. The potential for DNAPL is considered likely if concentrations of DNAPL-related chemicals in soils are greater than 10,000 mg/kg (equal to 1% of soil mass) based on laboratory data [Environmental Protection Agency (EPA), 1993]. All three samples collected immediately above the bedrock exceeded 10,000 mg/kg of carbon tetrachloride. Radionuclide activities in the subsurface soil samples were at background levels.

Groundwater Samples

Groundwater samples were collected using Hydropunch® sampling equipment in each open borehole (see Figure 2-1). A nonaqueous liquid was observed in the fluid sample collected at location 02895. Dissolved carbon tetrachloride was detected in groundwater samples at 02695, 02795, and 02995 at 2,000 µg/L, 1,500 µg/L, and 390 µg/L, respectively. Carbon tetrachloride's aqueous solubility is 825 milligrams per liter (mg/L) (i.e., 825,000 µg/L) at 20° C (Pankow and Cherry, 1996). Results for organic compounds detected in the groundwater collected from borehole locations are provided in Table 2-5. The RFCA Ground Water Action Levels are also listed for comparative purposes. As indicated, the dissolved concentrations of carbon tetrachloride in groundwater samples from locations 02695 and 02795 are above the RFCA Groundwater Action Levels. Dilution of the samples to bring the analytes into the detection range of the gas chromatograph/mass spectrometer resulted in elevated detection limits for many organic compounds. As a result, these compounds may be present at concentrations below these elevated detection limits; however, as shown in Table 2-5, many potential degradation products and semivolatiles were detected above the elevated detection limits despite this masking effect. Laboratory results for radionuclide activities in groundwater samples are also provided in Table 2-5.

Table 2-5. Organic Compounds (µg/L) and Radionuclides (pCi/L) Detected In OU 9 RFI/RI Groundwater Samples.

Compound	RFCA Tier I Groundwater Action Level (µg/L)	Boring/Hydropunch® Location (µg/L)			
		02695	02795	02895	02995
Acetone	365,000	ND	110	ND	13
Carbon Tetrachloride	500	2000	1500	ND	390
Chloroform	11,000	1200	450	ND	620
Methylene Chloride	500	22	ND	ND	ND
Tetrachloroethene	500	12	14	ND	ND
2-Methylnaphthalene	-	ND	ND	100	ND
4-Methyphenol	-	ND	ND	150	ND
Naphthalene	146,000	ND	ND	32	ND
Phenanthrene	-	ND	ND	12	ND
Phenol	2,190,000	ND	ND	100	ND
Americium-241	14.5	0.092	0.008	0.410	0.539
Plutonium-239/-240	15.1	0.089	0.026	2.453	0.058
Radium-226	2000	ND	1.3	2.9	33
Tritium	66,600	115	-109	-19	-49
Uranium-233/-234	298	29.09	9.20	5.67	17.32
Uranium-235	101	1.04	0.40	0.48	0.53
Uranium-238	76.8	20.73	6.87	5.37	17.42

2.3.2 Pre-Remedial Investigation Sampling

Additional sampling and analysis was performed in September of 1997 to determine the nature and extent of the DNAPL. The results of this investigation are summarized below and detailed in the Final Pre-remedial Investigation of IHSS 118.1 Data Summary Report (RMRS, 1997b).

Subsurface Soils

The primary contaminant detected in soil in the investigation area was carbon tetrachloride, along with lesser amounts of chloroform and methylene chloride. Both methylene chloride and chloroform are reductive dehalogenation products of carbon tetrachloride; however, both chemicals were used on site, with chloroform known to have been used in Building 776. Table 2-6 provides the analytical results for the primary contaminants and other compounds detected for each subsurface soil sample. Methylene chloride was encountered at all depths with detectable concentrations of 0.330 to 2.0 mg/kg. The highest concentrations of carbon tetrachloride and chloroform in soils are found at depths greater than 20 feet below ground surface. These data agree with the previous investigation, and indicate that the DNAPL may be present only at that depth (RMRS 1997b).

As shown in Table 2-6, other contaminants were found in the soil samples. These contaminants are not consistently present and, where duplicate samples were collected, do not occur in both the real and duplicate samples. Only one sample yielded results for these other contaminants above the detection limit; tetrachloroethene at 1,800 micrograms/kilogram ($\mu\text{g/kg}$) and carbon disulfide at 910 $\mu\text{g/kg}$. However, the duplicate sample for this interval did not contain detectable quantities of either contaminant. Naphthalene was observed in one sample; however, naphthalene was also detected in the blank. As a result it is probably not representative of the contamination at this location. The results of the radiological samples with activities above background are provided in Table 2-7. These samples were collected from the upper 3 feet of the core.

Groundwater

In support of the pre-remedial investigation sampling, wells were installed at 6 locations, water levels were measured and groundwater samples were collected. Groundwater was present 6 to 9 feet below ground surface (Table 2-1), and the DNAPL appears to occur in a thin layer directly above the bedrock contact. Depth to DNAPL was verified with an interface probe at one location (05497) at a depth of 21 feet below ground surface. Separate groundwater and DNAPL samples from 4 locations (05397, 05497, 05897 and 05997) were collected. The contaminants detected in these samples are the same as those observed in the subsurface soil samples: primarily carbon tetrachloride with lesser amounts of chloroform and methylene chloride. As previously mentioned, methylene chloride and chloroform are reductive dehalogenation products of carbon tetrachloride, but both were also used on site (RMRS, 1997b). Table 2-8 presents the results of the groundwater and DNAPL analyses. As noted in the data summary report, groundwater concentrations observed are higher than those samples collected during the 1995 investigation (RMRS, 1997b).

Table 2-6. Pre-Remedial Action Investigation - Subsurface Soil Contaminants (mg/kg) and Corresponding RFCA Action Levels.

Compounds Detected										
		Methylen e chloride	Carbon Tetra- chloride	Chloro- form	Tetrachloro -ethene	Naph- thalene	Hexachloro- butadiene	Acetone	Carbon Disulfide	Hexachloro- Ethane
RFCA Tier I Subsurface Soil Action Level (mg/kg):		5.77	11	152	11.5	5,770	17.3	2,740	43.2	36.4
Location	Depth	Sample Results								
05197	2.0-2.3	0.610 J	ND	ND	ND	ND	ND	ND	ND	ND
	2.8-3.1	0.610 J	ND	ND	ND	ND	ND	ND	ND	ND
	3.1-3.4	0.540 J	ND	ND	ND	ND	ND	ND	ND	ND
	5.4-5.7	0.560 J	ND	ND	ND	0.310 J,B	ND	ND	ND	ND
	6.7-7.0	0.580 J	ND	ND	ND	ND	ND	ND	ND	ND
	9.1-9.4	0.910	ND	ND	ND	ND	ND	ND	ND	ND
	14.0-14.3	0.950	ND	ND	ND	ND	ND	ND	ND	ND
	14.6-14.9	0.910	ND	ND	ND	ND	ND	ND	ND	ND
	17.8-18.1	1.1	ND	ND	0.680	ND	ND	ND	ND	ND
	19.1-19.3	1.1	ND	ND	0.560 J	ND	ND	ND	ND	ND
05297	21.1-21.4	1.1	0.780	ND	0.510 J	ND	ND	ND	ND	ND
	26.0-26.5	1.4	12	50 E	ND	ND	ND	ND	ND	ND
	2.8-3.1	1.1	ND	0.320 J	ND	ND	ND	ND	ND	ND
	6.6-6.9	0.870	ND	ND	ND	ND	ND	ND	ND	ND
	10.8-11.0	0.920	ND	ND	ND	ND	ND	ND	ND	ND
	12.9-13.2	0.880	ND	ND	ND	ND	ND	ND	ND	ND
	16.6-16.8	0.990	ND	ND	ND	ND	ND	ND	ND	ND
	21.0-21.2	0.880	6.0	ND	ND	ND	ND	ND	ND	ND
	26.2-26.4	0.710	0.570 J	ND	ND	ND	ND	ND	ND	ND
	05397	2.2-2.5	0.770	ND	ND	ND	ND	ND	ND	ND
	7.0-7.3	0.330 J	ND	ND	ND	ND	ND	ND	ND	ND
	10.3-10.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
	10.5-10.7	ND	ND	ND	ND	ND	ND	ND	ND	ND
	14.4-14.7	ND	ND	ND	ND	ND	ND	ND	ND	ND
	17.8-18.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
	21.2-21.5	ND	8.1	0.270 J	ND	ND	ND	ND	ND	ND

Table 2-6. (continued)

Compounds Detected										
		Methylene chloride	Carbon Tetra- chloride	Chloro- form	Tetrachlor o-ethene	Naph- thalene	Hexachloro - butadiene	Acetone	Carbon Disulfide	Hexachloro- Ethane
RFCA Tier I Subsurface Soil Action Level (mg/kg):		5.77	11	152	11.5	5,770	17.3	2,740	43.2	36.4
Location	Depth	Sample Results								
05397 (cont)	24.25-24.5	ND	370 E	2.9	ND	ND	0.560 J	ND	ND	ND
	26.3-26.5	ND	7.2	ND	ND	ND	ND	ND	ND	ND
05497	1.9-2.2	1.5 B	0.460 J	ND	ND	ND	ND	ND	ND	ND
	5.8-6.0	1.4 B	0.570 J	ND	ND	ND	ND	ND	ND	ND
	9.0-9.3	1.5 B	0.530 J	ND	ND	ND	ND	ND	ND	ND
	13.4-13.7	1.4 B	0.600 J	ND	ND	ND	ND	ND	ND	ND
	19.5-19.8	0.300 JB	4.5	1.6	ND	ND	ND	ND	ND	ND
	23.9-24.2	0.310 JB	3.2	2.2	ND	ND	ND	ND	ND	ND
	25.7-26.0	ND	51 E	1.8	ND	ND	0.900 J	ND	ND	12 J
05597	3.2-3.5	0.630	ND	ND	ND	ND	ND	0.260 J	ND	ND
	5.5-5.8	0.600 J	ND	ND	ND	ND	ND	ND	ND	ND
	11.1-11.4	0.370 J	ND	ND	ND	ND	ND	ND	ND	ND
05697	1.4-1.7	ND	0.390 J	ND	ND	ND	ND	ND	ND	ND
	4.8-5.0	1.4 B	1.2	ND	ND	ND	ND	ND	ND	ND
	8.6-8.9	1.4 B	5.4	ND	ND	ND	ND	ND	ND	ND
	12.8-13.1	1.4 B	1.4	ND	ND	ND	ND	ND	ND	ND
	19.5-19.7	1.3 B	0.720	ND	ND	ND	ND	ND	ND	ND
05797	3.0-3.3	ND	0.670	ND	ND	ND	ND	ND	ND	ND
	5.5-5.7	ND	0.370 J	ND	ND	ND	ND	ND	ND	ND
	5.7-6.0	0.620 J	0.280 J	ND	ND	ND	ND	ND	ND	ND
	11.2-11.5	0.610 J	ND	ND	ND	ND	ND	ND	ND	ND
05897	2.2-2.5	0.340 J	ND	ND	ND	ND	ND	ND	ND	ND
	5.6-5.8	ND	ND	ND	ND	ND	ND	ND	ND	ND
	5.8-6.1	0.250 J	ND	ND	ND	ND	ND	ND	ND	ND
	8.4-8.6	0.260 J	ND	ND	ND	ND	ND	ND	ND	ND
	12.3-12.6	0.270 J	ND	ND	ND	ND	ND	ND	ND	ND
	16.5-16.7	ND	0.610 J	ND	ND	ND	ND	ND	ND	ND
	20.4-20.7	0.790	450 E	71 E	1.8	ND	1.5	ND	910	31 J
	20.7-21.0	2.0 B	1.2	0.250 J	ND	ND	ND	0.500 J	ND	ND
05997	1.4-1.6	1.1 B	ND	ND	ND	ND	ND	ND	ND	ND
	5.8-6.1	1.7 B	ND	ND	ND	ND	ND	ND	ND	ND
	9.1-9.4	1.5 B	ND	ND	ND	ND	ND	ND	ND	ND
	12.8-13.1	1.4 B	1.8	1.9	0.290 J	ND	ND	ND	ND	ND
	16.7-17.0	1.4 B	0.460 J	0.540 J	ND	ND	ND	ND	ND	ND
	20.1-20.4	ND	12	ND	ND	ND	680	ND	ND	8.1 J
	20.9-21.2	1.3 B	370 E	0.730	0.480 J	ND	0.560 J	ND	ND	10 J
	Slough ~25'	1.5 B	390 E	35 E	0.550 J	ND	0.510 J	ND	ND	9.7 J
	Slough ~25'	1.4 B	140 E	12	ND	ND	ND	ND	ND	ND

E - estimated value, concentration outside of calibration range
J - estimated value, concentration is below the detection limit
B - analyte also detected in the blank analysis.

Table 2-7. Radionuclides Detected in Pre-remedial Action Investigation Soils (pCi/g) and Corresponding RFCA Action Levels.

Radionuclides Detected			
		Pu-239/240	Am-241
RFCA Tier II Surface Soil Action Levels:		252	38
Location	Depth (ft)	Sample Results	
05197	2.4 - 2.8	—	0.049 (0.060)
05297	2.2 - 2.6	—	0.044 (0.098)
05397	1.8 - 2.2	—	—
05797	1.0 - 1.4	—	—
05597	0.8 - 1.5	—	0.087 (0.098)
05897	1.6 - 2.2	—	—
05997	0.8 - 1.4	—	0.063 (0.063)
05997	0.2 - 0.8	0.192 (0.091)	—
05697	0.8 - 1.4	—	—
05497	1.5 - 1.9	0.256 (0.120)	0.105 (0.089)

— = Result is not above background.
() = Value represents uncertainty (i.e., total error).

Table 2-8. Groundwater/DNAPL VOC Results For IHSS 118.1 Investigation (µg/L) and Corresponding RFCA Action Levels.

Well	Sample No	Methylene Chloride	Carbon Tetrachloride	Chloroform	Physical Description of Collected Sample
Groundwater Samples					
RFCA Groundwater Tier I Action Levels (µg/L)		500	500	11,000	
05197	GW10016RM	2,300 J	240,000 E	35,000	Very silty water, possible DNAPL droplets present
05397	GW10019RM	25,000 JB	680,000	26,000 J	Water layer above DNAPL, very thin LNAPL* slick present
05497	GW10023RM	180,000	1,100,000 E	< 5,000,000	Water layer above DNAPL - sample vial had <10% separate phase DNAPL and thin LNAPL slick
05697	GW10017RM	190 J,B	6,600	3,500	No DNAPL observed
05897	GW10020RM	32,000 JB	510,000	88,000	Water layer above DNAPL
05997	GW10024RM	13,000 J	880,000	160,000	Water layer above DNAPL - vial had up to 25% separate phase DNAPL
DNAPL Samples					
05397	GW10022RM	< 5,000,000	120,000,000	< 5,000,000	DNAPL sample - sample vial had up to 40% water as a separate phase.
05497	GW10018RM	2,500,000	180,000,000 E	2,700,000	DNAPL sample (real)
05497	GW10026RM	3,600,000 J	130,000,000	< 5,000,000	DNAPL sample (duplicate)
05897	GW10025RM	2,600,000 J	250,000,000 E	3,800,000 J	DNAPL sample
05997	GW10021RM	< 5,000,000	240,000,000 E	3,600,000 J	DNAPL sample

* Light nonaqueous phase liquid (LNAPL) is organic fraction that has been tentatively identified as No. 2 Diesel Fuel Oil.
E - estimated value, concentration outside of calibration range
J - estimated value, concentration is below the detection limit
B - analyte also detected in the blank analysis.

The samples were also analyzed for total petroleum hydrocarbons due to the dark brown color of the DNAPL samples, since pure-phase carbon tetrachloride is colorless. As shown in Table 2-9, the light nonaqueous phase liquid (LNAPL) is a semi-volatile hydrocarbon that is likely a fuel oil or fuel-like mixture of hydrocarbons such as number 2 (diesel) fuel oil. The original source of the LNAPL is unknown. Although there are numerous underground and above ground fuel oil tanks in the area, it does not appear that these tanks are a source of the diesel. These tanks were investigated as part of the Underground Storage Tank replacement program as described in Attachment 13 of RFCA. None of the soil samples taken from around these tanks had total petroleum hydrocarbon levels above 5,000 parts per million, and no further investigative or remedial activities are currently planned. Additional information on the fuel storage tanks will be released in a final closure report in the near future.

In samples from most wells, the analytical results for groundwater above the DNAPL layer indicated significantly lower concentrations of fuel oil than the underlying DNAPL layer. However, groundwater samples from wells 05497 and 05997 contained similar concentrations of fuel oil as the underlying DNAPL samples from these wells. Both of these groundwater samples also contained a DNAPL as a separate phase. Due to the similar concentrations of fuel oil observed in the DNAPL and the groundwater samples from these wells, it is likely that the DNAPL phase present in these two groundwater samples was analyzed.

Table 2-9. Total Petroleum Hydrocarbon Results.

Location	Sample No	No. 2 Diesel Fuel	Jet Fuel - Kerosene	Motor Oil	Physical Description of Collected Sample
Groundwater Samples					
05197	GW10016RM	<6.2 mg/l	<6.2 mg/l	<9.4 mg/l	Very silty water, possible DNAPL droplets present
05397	GW10019RM	<6.2 mg/l	<6.2 mg/l	<9.4 mg/l	Water layer above DNAPL, very thin LNAPL slick present
05497	GW10023RM	3,200 mg/kg	<250 mg/kg	<250 mg/kg	Water layer above DNAPL - sample vial had <10% separate phase DNAPL and a thin LNAPL slick
05697	GW10017RM	<6.2 mg/l	<6.2 mg/l	<9.4 mg/l	No DNAPL observed
05897	GW10020RM	<6.2 mg/l	<6.2 mg/l	<9.4 mg/l	Water sample above DNAPL
05997	GW10024RM	2,700 mg/kg	<250 mg/kg	<250 mg/kg	Water layer above DNAPL - vial had up to 25% separate phase DNAPL
DNAPL Samples					
05397	GW10022RM	1,700 mg/kg	<250 mg/kg	<250 mg/kg	DNAPL sample - sample vial had up to 40% water as a separate phase
05497	GW10018RM	3,100 mg/kg	<250 mg/kg	<250 mg/kg	DNAPL (real sample)
05497	GW10026RM	3,200 mg/kg	<250 mg/kg	<250 mg/kg	DNAPL (duplicate sample)
05897	GW10025RM	2,600 mg/kg	<250 mg/kg	<250 mg/kg	DNAPL sample
05997	GW10021RM	2,600 mg/kg	<250 mg/kg	<250 mg/kg	DNAPL sample

2.4 EXISTING CONDITIONS

Based on the information gathered during the pre-remedial investigation implemented in September 1997, coupled with the available information for IHSS 118.1 and Tanks T-9 and T-10, an east-west cross-section illustrating the existing conditions for the site was developed (Figure 2-5). A carbon tetrachloride zone originating from the former location of the carbon tetrachloride tank in IHSS 118.1 extends east to the T-9/T-10 tank pit. As illustrated by the cross-section (Figure 2-5), the impermeable claystone bedrock limits the vertical migration of carbon tetrachloride and the depression created in the bedrock surface limits the areal extent of the DNAPL zone. Based on the findings of the investigations, it is assumed that the DNAPL zone is limited to the bedrock depression and below ground water flow streamlines. The stagnant water

created in this depression limits both mass transport of the carbon tetrachloride and isolates the DNAPL from oxygen so that excess electrons can reduce the chlorinated solvents.

RMRS (1997b) concluded that, due to the high concentrations of carbon tetrachloride and the lack of radiological contamination, the DNAPL is assumed to be a result of spills and leaks from the carbon tetrachloride storage tank. Because both the DNAPL samples and high concentrations in soil are found only near the bottom of the excavation, the DNAPL zone is thought to occur in a vertical interval, approximately one-foot thick above the bedrock surface at the bottom of the depression. The zone of carbon tetrachloride may fill the bottom of the excavation, including areas underneath Tanks T-9 and T-10 and the associated sump. However, there is a likelihood that the DNAPL is in pockets at several intervals near the bottom of the excavation due to the mixed permeability of the fill, as opposed to a continuous shallow layer.

Installation of the wells could have intercepted several small pools which then drained into the well, giving the appearance of a single pool of DNAPL. Insufficient data exists to fully differentiate between these scenarios. However, as the DNAPL is thought to occur within a one-foot interval near the bottom of the excavation, it is likely that the DNAPL is perched on undisturbed bedrock claystone (RMRS, 1997b).

The zone where the DNAPL resides is comprised of two liquid phases: the groundwater that has not been displaced and the DNAPL that is trapped in pores and fractures. Due to its surface chemistry, the soil has a greater affinity for water. This characteristic is called wettability. Because the water is the wetting fluid, it is not completely displaced by the DNAPL in this zone. Water will coat the soil particles and remain in the smaller pores. Although DNAPL is not in the smaller pores, it is trapped in the larger pores. The migration of DNAPL through these pores is controlled by capillary pressure which will hold the DNAPL in pore material. This capillary pressure is particularly significant in fine grained media. The capillary pressure will inhibit migration but will also keep DNAPL from being recovered through a pumping system. Figure 2-5 illustrates the two-phase nature of the DNAPL zone.

The low-permeability claystone at the bottom of the excavation acts as a barrier to prevent substantial downward migration of the carbon tetrachloride, while the groundwater above prevents evaporation. The vertical migration of DNAPL into bedrock was evaluated by an earlier study, which concluded that there is no apparent threat to surface water or to deeper aquifers (RMRS 1996). All occurrences of the DNAPL layer are at too great of depths to migrate along utility corridors or along the original bedrock surface. Therefore, the only risk to surface water is through migration of the dissolved phase in groundwater (RMRS, 1997b).

To develop a gross estimate of the potential volume of DNAPL that may be present, the depths to the observed DNAPL and high soil concentrations were used to estimate a thickness for the DNAPL. Using this information, estimates of the potential volume of DNAPL were calculated using three different methods (RMRS, 1997b). Accounting for the displacement of the sump, the estimated volume of DNAPL that could potentially reside in the fill material below the tank ranges from 8 and 2,900 gallons. Based on a range of conservative recovery rates of 5 to 15 percent, the recoverable volume of DNAPL could be between from less than one gallon to 400 gallons. A more detailed description of these calculations can be found in the *Final Pre-Remedial Investigation of IHSS 118.1 Data Summary Report* (RMRS, 1997b).

Although the DNAPL appears to be confined to the area of the T-9 and T-10 excavation, the dissolved plume is not confined by these physical constraints. To evaluate the fate and transport of the dissolved plume, the mass flow rate of carbon tetrachloride was evaluated. Table 2-10 presents the results of this evaluation. The flow rate across IHSS 118.1 was calculated using a gradient based on water levels and the saturated thickness in the alluvium. Because the concentration is based on groundwater that is from both the alluvium and water contained in the bedrock depression, the concentrations are probably much higher than they would be for the alluvium alone. For this reason, the reduction in mass flow rate between the

IHSS and the foundation drain may be due more to the containment of contaminated water in the bedrock depression than due to degradation. The calculation of the mass flow rate is presented in Appendix B of this document.

This model assumes that most of the water will be captured in the Building 771 foundation drain. As seen in Figure 2-4, this foundation drain greatly influences groundwater flow at IHSS 118.1 due to its size, depth and proximity to the release area. The foundation drain data in the table is from sample location FD 771-4. It should be noted that there are two additional lines for this foundation drain; however, there are also other sources of carbon tetrachloride that contribute to the mass flux. The flows from these other two lines from Building 771 that have not been sampled are anticipated to also be low. Three lines from the foundation drains around Building 774 to the northeast of the site have also been sampled and carbon tetrachloride was not detected at any of these locations. As evidenced by this data, the total mass flow rate (mass/time) of carbon tetrachloride displays an apparent decrease as the contaminants migrate away from the release area. Since the Building 771 foundation drain is only about 100 feet downgradient of the DNAPL, the low concentrations in the drain suggest that contaminant migration is being severely limited by containment within the tank excavation and through attenuation process such as dilution and degradation. Due to the complexity of flow through the bedrock depression and unknowns concerning the nature of the DNAPL zone, the estimated mass flow rate across the IHSS 118.1 source area has a high degree of uncertainty. Nevertheless, even accounting for this uncertainty, there still would be a significant reduction in carbon tetrachloride that could be attributed to attenuation.

Table 2-10 Estimated Mass Flow Rate of Carbon Tetrachloride

Location	Liquid Flow Rate (gpm)	Concentration (lg/L)	Mass Flow Rate (g/min)
Across IHSS 118.1	0.077	792,500 (Average)	0.231
771 Footing Drain*	1.0	43	1.63×10^{-4}
Surface Water Location SW-093	90	Not Detected	Not Detected

* Note - This data is from sample location FD 771-4.

2.5 NATURAL ATTENUATION PROCESSES

Natural attenuation includes physical, chemical and biological processes that limit or control contaminants in the environment. This may include any or all of the following processes:

- Chemical Transformation,
- Biodegradation,
- Dilution,
- Dispersion,
- Sorption, and
- Volatilization

At IHSS 118.1, dilution, dispersion, volatilization, and chemical transformation could all possibly play key roles in reducing downgradient contaminant concentrations. Physical processes could be as effective as degradation in controlling contaminants. As mentioned in Section 2.4, the geometry of the bedrock depression likely limits contaminant migration to that which can diffuse out of the depression into the groundwater flow in the Rocky Flats Alluvium. Dilution probably also plays a role once the contaminants reach downgradient footing drains and are mixed with cleaner groundwater from other parts of the Industrial Area.

There are a number of potential mechanisms that could degrade or limit the mobility of carbon tetrachloride at IHSS 118.1. Reductive dechlorination is the most promising mechanism for transformation because it can result in the destruction of carbon tetrachloride. Data gathered from past investigations indicate that, not only are there favorable conditions for reductive dechlorination, but also that it is likely occurring. Three mechanisms for chemical/biological degradation of chlorinated aliphatics have been identified (Wiedemeir, et al, 1997).

1. **Electron Acceptor Reactions (Reductive Dechlorination)** - Under this process the carbon tetrachloride (an electron acceptor) is chemically transformed through the reductive environment created by the biodegradation of another carbon source. Of the three degradation processes, this is the most effective for the biodegradation of chlorinated solvents. Reductive dechlorination takes the following steps:
 - First, biodegradation of a carbon source (such as a petroleum hydrocarbon) occurs and creates an excess of electrons (i.e., a reducing environment). Carbon tetrachloride itself cannot act as the substrate because its oxidation state is too high.
 - Second, as the available electrons increase, the chemical species that are easiest to reduce will be transformed first. The order in which dissolved species will be reduced as proposed by Strumm and Morgan (1981) is as follows:
 1. Dissolved Oxygen (O_2) Reduction
 2. Reduction of Manganese (IV) to Manganese (III)
 3. Nitrate (NO_3^-) Reduction
 4. Reduction of Ferric (Fe^{3+}) to Ferrous (Fe^{2+}) Iron
 5. Reduction of Sulfate (SO_4^{2-})
 6. H_2 Reduction
 - Finally, after the reduction of these dissolved species, the DNAPL will be reduced through dechlorination. Specifically, the carbon tetrachloride is reduced through the replacement of the chlorine atom with a hydrogen atom.
2. **Electron Donor Reactions (Oxidation)** - In these reactions, the less-oxidized organic compounds act as a substrate for biodegradation. These organic molecules move towards a more oxidized state. The end product of these reactions is carbon dioxide. Due to its oxidation state, carbon tetrachloride is not a good electron donor and therefore not suitable as a primary substrate; however, the less-oxidized by-products of other degradation reactions such as methylene chloride could be suitable donors and could serve as a substrate.
3. **Co-metabolization** - The degradation of carbon tetrachloride would be catalyzed by an enzyme or a co-factor produced by microbes metabolizing some other food source.

Based on the results from past investigations, reductive dechlorination appears to be occurring near the DNAPL/groundwater interface and the degradation products are potentially undergoing oxidation farther out from the DNAPL zone. This would suggest that there is a reduction zone rich in available electrons around the T-9/T-10 Tanks. The conceptual model is shown as Figure 2-6 is based the results of the previous investigations.

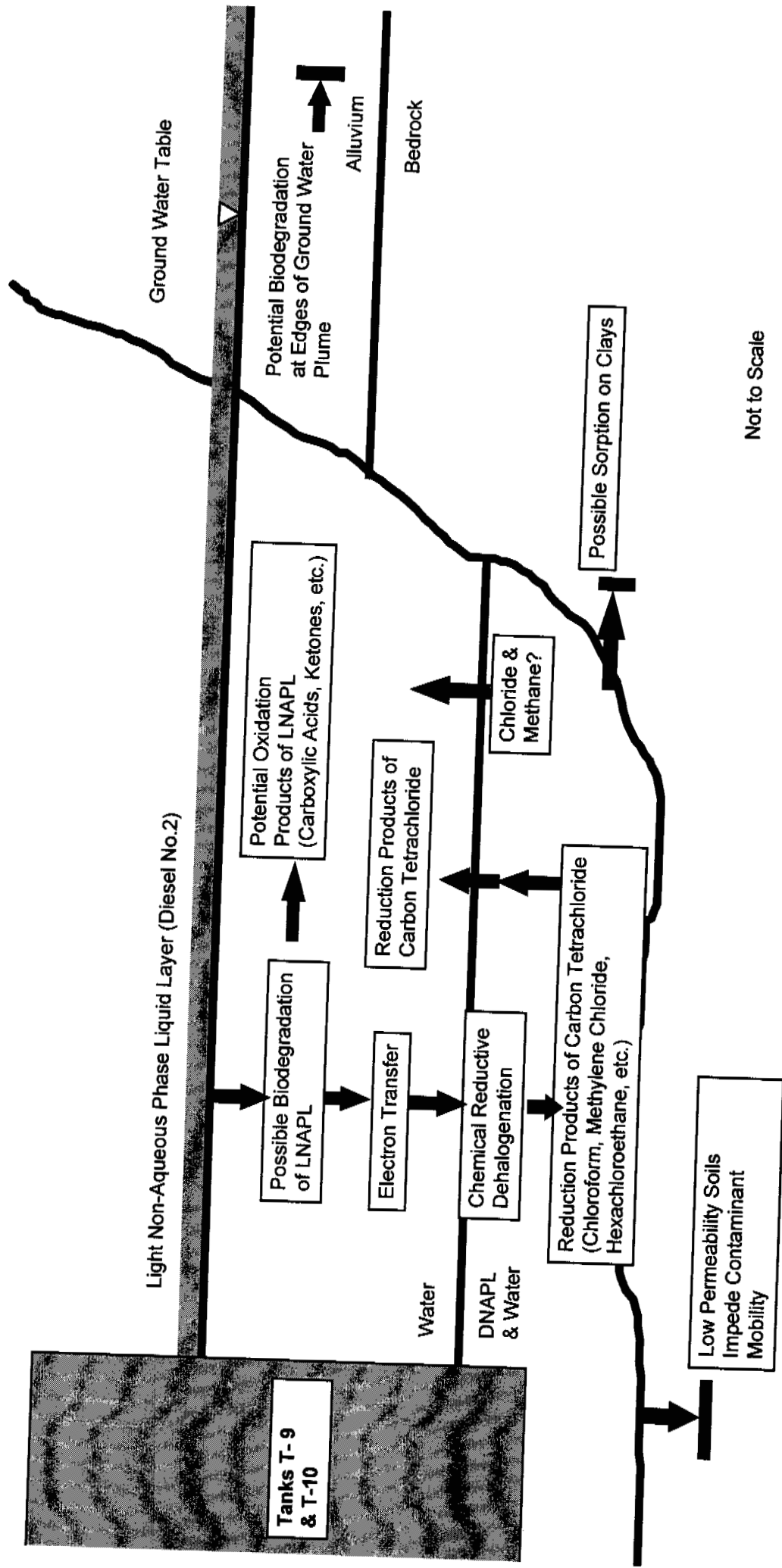
Enough evidence exists at this time to validate that reductive dechlorination is occurring. The following observations support the concept that reductive dechlorination of DNAPL and dissolved organic solvents is occurring:

- Possible carbon tetrachloride degradation products are present in the soil, groundwater, and the DNAPL. These compounds include chloroform, methylene chloride, and carbon disulfide. All of these compounds are degradation products for reduction reactions. It is believed that all of the spills of DNAPL were probably of unused carbon tetrachloride. Because the carbon tetrachloride was utilized in plant operations, it was probably an industrial grade. Chloroform and methylene chloride were widely distributed in both the aqueous and nonaqueous phases. Reductive dehalogenation could explain the pervasiveness of these compounds
- Non-chlorinated hydrocarbons (No. 2 Diesel) are present that could act as a substrate for biological activity in the water phase. The light nonaqueous phase liquid that was detected provides ideal conditions for the most aggressive biodegradation process (reductive dehalogenation).
- Oxidized non-chlorinated hydrocarbons, such as carboxylic acids and ketones, were detected during the OU 9 investigation that could be the result of aerobic biodegradation.

In addition to degradation of chlorinated solvents, physical factors are controlling the migration of contaminants. Natural dilution probably has an effect on contaminant concentrations in the foundation drains or surface water but it is containment and isolation of the DNAPL at the source that appears to have a far greater overall effect. Because the DNAPL resides in a bedrock depression approximately 12 to 13 feet below the normal bedrock surface, the DNAPL is not exposed to the main groundwater flow in the Rocky Flats Alluvium. Due to the relatively low permeability of the fill material in and above the DNAPL zone and the characteristics of groundwater flow in the area, it is likely that the water above the DNAPL is stagnant and that diffusion rather than advection is controlling the mass transport of the contaminants. This is a significant effect, since the rate of mass transfer would be significantly less through diffusion alone and concentrations in the groundwater moving over the top of the bedrock depression should be significantly less than water near the DNAPL.

The evidence that natural attenuation is occurring, regardless of the specific mechanism, can be found at downgradient sampling stations. As discussed in Section 2.4, although the spill is relatively old, concentrations in the foundation drains are low or non-detectable. This includes the footing drains for Buildings 771 and 774. This suggests that natural attenuation processes, such as degradation, diffusion, and dilution might be actively limiting migration of dissolved carbon tetrachloride. At the downstream surface water location, SW-093, no carbon tetrachloride has been detected and VOCs are low or non-detectable.

Figure 2-6 Conceptual Model of Natural Attenuation Mechanisms



3.0 PROJECT APPROACH

Based on the alternative analysis in Appendix A, Monitored Natural Attenuation was selected as the best approach for IHSS 118.1 to address risk prior to the determination of a final action. Unique site conditions at IHSS 118.1 are very favorable to natural processes that control and limit the migration of carbon tetrachloride. The historical absence of contaminants in surface water suggests that natural attenuation appears to be effectively limiting the migration of contaminants and thereby protecting surface water. In addition, this approach will provide downgradient monitoring to validate the protection of surface waters. The selection was also based on the inability to implement other technologies for source zone restoration due to inaccessibility. Partial source removal through pumping or other means is ineffective because residual DNAPL would not be completely recovered and would continue to contaminate groundwater. Furthermore, even with complete removal or containment of the carbon tetrachloride at IHSS 118.1, other sources in the Industrial Area would continue to supply carbon tetrachloride to the groundwater plume.

3.1 OBJECTIVES

The objectives of the proposed action are to demonstrate that the IHSS 118.1 plume does not impact surface water and will not in the future.

Corollary Objectives:

- a. Promote consistency with and contribute to the efficient performance of final response actions.
- b. Determine the carbon tetrachloride plume's axial extent downgradient in the direction of surface water receptors.

3.2 DATA QUALITY OBJECTIVES

The data needed to monitor natural attenuation at IHSS 118.1 will be determined using the process in *Guidelines for Data Quality Objective Process*, EPA QA/G4 (EPA, 1994) using the objectives listed above. These data quality objectives will be developed in the preparation of the revision to the IMP (Kaiser-Hill, 1997) or in a sampling and analysis plan (SAP). The primary sampling and analytical needs are as follows:

- To monitor contaminant containment
- To monitor natural attenuation control of contaminant migration
- To ensure protection of surface water
- To establish background concentrations of key parameters
- To determine groundwater flow direction

Once the data is received, the data will be compared to project specific data quality objectives. Data validation will be performed on a minimum of 25% of the data using the precision, accuracy, reproducibility, completeness, and comparability (PARCC) parameters established by EPA guidelines, DOE data management practices and the Rocky Mountain Remediation Services (RMRS) *Quality Assurance Project Description* (QAPD) (RMRS, 1997c).

3.3 PROPOSED APPROACH

The proposed IHSS 118.1 approach, Monitored Natural Attenuation, will evaluate if natural attenuation and containment of the source mitigate potential risks to surface water posed by the DNAPL. In order to ensure protection of surface water, data collected will be evaluated to determine the magnitude of natural attenuation processes, such as containment and degradation. All activities will be integrated with existing RFETS monitoring activities under the IMP (Kaiser-Hill, 1997). Monitoring is planned to continue until

enough data is collected to perform trend analysis. The elements of the monitoring program will be as follows:

1. Install four additional downgradient monitoring wells which will be used to sample for carbon tetrachloride and associated indicators of natural attenuation. The wells will be in a east-west line north of the site with an additional well to the east (see Figure 2-4).
2. Install two upgradient wells to determine background concentrations (See Figure 2-4).
3. Analyze groundwater in wells near IHSS 118.1 for reductive dehalogenation products such as chloroform, methylene chloride, and chloromethane in addition to analyzing for chemical conditions favorable for reductive dehalogenation. The analysis will determine whether there are promising trends in the measured parameters.
4. Analyze DNAPL to determine relative ratios of carbon tetrachloride and reductive dehalogenation products and observe if these concentrations change with time.
5. Measure water levels and the depth and thickness of the DNAPL zone. This would allow the opportunity to further evaluate the nature of the DNAPL in the soil.
6. Evaluate groundwater flow direction and the gradient.
7. Monitoring of IHSS 118.1 will be integrated into the current program under the IMP. This will include sampling, analysis, data evaluation, and reporting. Evaluation of the data will be incorporated into the RFETS Annual RFCA Groundwater Monitoring Report.
8. Sample the 771 footing drain line for chlorinated solvents to determine whether the plume has reached the footing drain.

The four downgradient wells will be used to determine if the plume migration is limited by natural attenuation and the degree to which reductive dehalogenation is occurring. Each well would be installed in accordance with RFETS monitoring well standards. The screen intervals will be approximately five to ten feet deep.

The wells that would be sampled include the six proposed wells plus the two of the wells (tentatively wells 05497 and 05897) installed around the T-9/T-10 tanks as part of the Pre-Remedial Investigation. These two wells may have to be reinstalled with larger diameter screens to meet the sampling requirements of the monitoring program. Table 3-1 presents the analytes to be sampled and the basis for each analyte. It is proposed that the first round of sampling would include all of the analytes. The first round results would be evaluated to determine which analytes were useful for assessing natural attenuation processes. An evaluation report would be prepared documenting this analysis. Sampling would be performed semiannually or annually in conjunction with activities under the RFETS IMP (Kaiser-Hill, 1997). For each year of sampling, an evaluation of these results would be incorporated into the Annual RFCA Groundwater Monitoring Report. At the end of the evaluation period, the sampling results would be evaluated a final time to determine the effectiveness of natural attenuation.

The attenuation of lighter-phase hydrocarbons, tentatively identified as Diesel No.2 Fuel Oil, will be addressed along with the heavier-phase chlorinated contaminants at IHSS 118.1. Some of the analytical indicators in Table 3-1 such as total organic carbon, alkalinity, dissolved methane, etc., will be used to evaluate the interaction between the diesel and the carbon tetrachloride. Downgradient monitoring will be used to determine whether natural attenuation is limiting the migration of the diesel. Releases of

Table 3-1: Potential Analytical Samples for Monitored Natural Attenuation Program

Analyte	Media	Analytical Location	Basis
Volatile Organic Compounds	Groundwater and DNAPL	Laboratory	Characterization of the types and concentration of organic contaminants
Sulfates	Groundwater	Laboratory	Electron acceptor, reduced concentrations from background suggests favorable condition for reductive dehalogenation
Sulfides	Groundwater	Laboratory	Reduced form of sulfur - presence is consistent with favorable conditions for reductive dehalogenation
Nitrate	Groundwater	Laboratory	Electron acceptor, reduced concentrations indicate anaerobic conditions
Iron	Groundwater	Laboratory	Electron acceptor, elevated concentrations indicate anaerobic conditions
Manganese	Groundwater	Laboratory	Electron acceptor, low concentrations indicate anaerobic conditions
Chloride	Groundwater	Laboratory	Levels above background are an indication of reductive dehalogenation
pH	Groundwater	Field	Characterization of basic water chemistry
Oxidation Potential	Groundwater	Field	Indicator of aqueous redox potential
Alkalinity	Groundwater	Laboratory	Elevated levels can be associated with oxidation of hydrocarbon to CO ₂ and H ₂ O
Methane	Groundwater	Laboratory	Presence of detectable methane is consistent with redox conditions that favor reductive dehalogenation
Total Organic Carbon	Groundwater	Laboratory	Absence or depressed levels are consistent with active degradation of nonchlorinated hydrocarbons and condition favorable for reductive dehalogenation
Dissolved Oxygen	Groundwater	Field	Higher concentrations would indicate that reduction is not occurring.
Dissolved Hydrogen	Groundwater	Laboratory	Source of hydrogen for reductive dehalogenation
Electrical Conductivity	Groundwater	Field	General water quality parameter
Temperature	Groundwater	Field	General water quality parameter

diesel identified at underground storage tanks in the vicinity is being addressed under the RFETS Underground Storage Tank Program as described in Attachment 13 to RFCA.

The footing drain(s) for Building 771 are an additional downgradient sampling point; however, because these lines have been moved it might not be possible to locate an appropriate sampling point. As part of this process, time will have to be spent reviewing engineering studies and other resources. Past attempts to locate this line have not succeeded. The drain lines will only be sampled for volatile organic compounds since significant degradation is not expected at this distance from the source. Further details on sampling and analysis will be presented in the SAP.

3.4 WORKER HEALTH AND SAFETY

This project falls under the scope of the Occupational Safety and Health Administration (OSHA) construction standard for Hazardous Waste Operations and Emergency Response, 29 Code of Federal Regulations (CFR) 1910.120. Under this standard, the Health and Safety Plan (HASP) currently utilized for groundwater monitoring will be revised to address the safety and health hazards of each phase of monitoring activities and specify the requirements and procedures for employee protection. In addition, the DOE Order for Construction Project Safety and Health Management, 5480.9A, applies to this project. This order requires the preparation of Activity Hazard Analyses (AHAs) to identify each task, the hazards associated with each task, and the precautions necessary to mitigate the hazards. The AHAs will be included in the HASP. This project could expose workers to physical and chemical hazards. Physical hazards include those associated with use of drilling equipment, noise, heat stress, and cold stress. Chemical hazards include exposure to the DNAPL and contaminated groundwater. Physical hazards will be mitigated by engineering controls, administrative controls, and appropriate use of personal protective equipment (PPE). Chemical hazards will be mitigated by the use of PPE and administrative controls. Appropriate skin and respiratory PPE will be worn throughout the project. Routine VOC monitoring will be conducted with an organic vapor monitor.

If unanticipated hazards or conditions are encountered during this project in accordance with RMRS policy (Directive-001), the project activities will pause to assess the potential hazard or condition to determine whether work can proceed with existing safety controls. If field conditions or hazards vary from the planned approach and it is determined that work can be done safely, an AHA will be prepared or modified to address the unexpected circumstances and work will proceed according to the appropriate control measures. Data and safety controls will be continually evaluated. Field radiological screening will be conducted as appropriate using radiological instruments appropriate to detect surface contamination and airborne radioactivity. As required by 10 CFR 835, Radiation Protection of Occupational Workers, all applicable implementing procedures will be followed to insure protection of the workers, collocated workers, the public, and the environment. The HASP will describe the air monitoring to be used to monitor for radiation, VOCs, and particulate, as appropriate. If necessary, air monitoring will be performed in accordance with applicable procedures which includes perimeter (Radioactive Ambient Air Monitoring Program [RAAMP]) monitoring throughout the project duration. Air monitoring activities may vary and are dependent on field activities.

3.5 REMEDIATION WASTE MANAGEMENT

Remediation waste anticipated from drilling and sampling includes recovered DNAPL, contaminated drill cuttings, purge water, PPE, and development water from well installation. All wastes will be managed in accordance with the RFETS standard operating procedure, Field Operations (FO).29 for

IDM under the existing IDM program. Wastes generated as part of this proposed action will be characterized based on process knowledge, analytical results, and radiological screening. Based on FO.29, wastes, such as PPE, identified as non-radiological and non-hazardous will be disposed in a sanitary landfill. Purge water will be treated at the 891 Consolidated Water Treatment Facility. It is anticipated that drill cuttings from wells near the source area will be managed as a RCRA hazardous waste and will be stored in a permitted unit until disposal.

4.0 ENVIRONMENTAL ISSUES

This section provides a description of potential environmental impacts which may be associated with monitored natural attenuation of IHSS 118.1. A consideration of alternatives is addressed in Appendix A of this document.

The proposed approach consists of drilling six new wells and then monitoring the wells, together with other existing wells, until the data are sufficient to establish a trend or a final remedy is effected. In addition to the six new wells, it may be necessary to reinstall two existing wells at larger diameters to enhance water recoveries. All new or reinstalled wells would be in the immediate vicinity of the tanks. Monitoring will be used to identify the extent to which natural attenuation processes are addressing the potential threat to surface water posed by the carbon tetrachloride. The six new wells would be to the north, east and south of Tanks 9 and 10 and drilled to the top of bedrock, a depth of less than 20 feet.

4.1 SOILS AND GEOLOGY

The environmental effects of installing or reinstalling eight shallow wells would be negligible. Each well would be exclusively within Rocky Flats alluvium and hence would pose no threat of inter-strata movement of contaminants or groundwater. Drill cuttings would be sampled and disposed of in accordance with RFETS procedures.

4.2 AIR

Well drilling and water monitoring do not have the potential to affect air quality significantly. A review by the Site's Air Quality Management Group indicates that effluent air monitoring will not be required and that the project is not subject to air emission inventory or APEN (Air Pollution Emissions Notice) requirements. Even if wells were drilled into contaminated soil or intercepted DNAPL, the quantity of hazardous air pollutants that would be released would be negligible. Operation of drilling equipment and vehicles used in later monitoring activities would emit small quantities of air pollutants.

4.3 WATER

As described in section 2.4, data indicate that carbon tetrachloride is present in groundwater, as well as in soil and as DNAPL, possibly under water, in the bedrock pit under Tanks 9 and 10. The proposed action will not worsen the extent or degree of groundwater contamination. Rather, it will observe the extent to which natural processes are neutralizing the problem by reductive dehalogenation. Neither the current source of contamination (the DNAPL beneath Tanks 9 and 10) nor the carbon tetrachloride in groundwater, are expected to change during the course of the monitoring.

4.4 HUMAN HEALTH

The carbon tetrachloride does not now present any threat to human health because it is isolated from the atmosphere and from sources of drinking water; this is not expected to change during the course of the monitoring. Workers will take appropriate precautions, such as wearing respirators to prevent possible exposure to carbon tetrachloride and other fumes during drilling.

4.5 FLORA AND FAUNA

The area where the wells are to be drilled is covered with gravel or is bare soil and essentially devoid of vegetation. In addition, terrestrial wildlife, with the exception of very mobile rabbits, raccoons and feral

cats, is largely absent from the RFETS Protected Area where drilling would occur. As a result, no impacts to flora or fauna are expected.

4.6 HISTORIC RESOURCES

Sixty-four of the Site's buildings have been declared eligible for the National Register of Historic Places and are subject to an Agreement between DOE and the State Historic Preservation Officer. However, no building is expected to be affected by the proposed action.

4.7 VISUAL RESOURCES

Installation or reinstallation of the wells and related monitoring activities would be expected to have no effects on the visual qualities of the highly-industrialized Protected Area.

4.8 NOISE

Drilling wells will result in a localized increase in noise levels for the approximate one day it will take to drill each well. Workers will wear protective equipment as appropriate.

4.9 CUMULATIVE EFFECTS

Drilling monitoring wells and monitoring attenuation of the carbon tetrachloride is part of the program to monitor IHSS 118.1 which, in turn, is part of the larger effort to cleanup RFETS and allow for other uses in the future. The cumulative effects of Site Cleanup are described in the Rocky Flats Cumulative Impacts Document, published in 1997 by the Rocky Flats Field Office (RFFO).

4.10 UNAVOIDABLE ADVERSE IMPACTS

No adverse impacts, other than negligible air emissions, are expected as a result of the proposed action.

4.11 SHORT-TERM USES VERSUS LONG-TERM PRODUCTIVITY

Natural attenuation monitoring is not expected to have any effects on short- or long-term uses or productivity of the area in question. The surface will not be disturbed except in the small areas around each of the new wells. It is expected that the subsurface conditions will be remediated by natural processes, improving long-term productivity. Ultimately, cleanup of the RFETS and removal of most of the Site's buildings will increase the potential for productive uses.

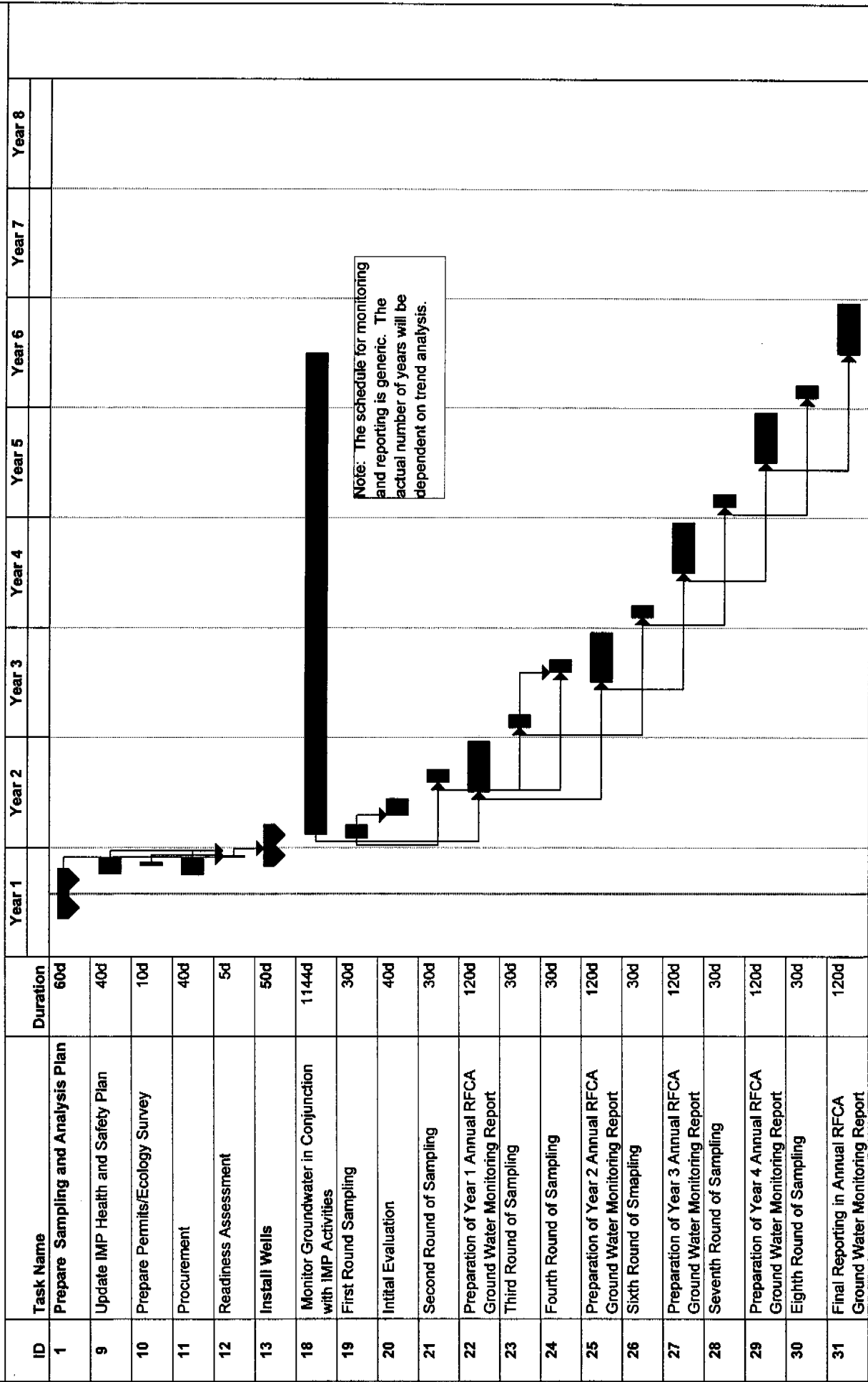
4.12 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

The well-drilling and water quality monitoring activities will consume fuels, money, and labor. None of these resources will be consumed in quantities that are significant relative to their consumption elsewhere across the Site.

5.0 IMPLEMENTATION SCHEDULE

The monitoring of natural attenuation processes at IHSS 118.1 is scheduled to commence in the fiscal year 1999. Figure 5-1 is a proposed schedule. The dates and durations of activities are subject to change due to regulatory and public concerns, budgetary constraints, weather delays, etc. The duration of monitoring will be based on trend analysis and could vary from what is shown in the schedule.

Figure 5-1 Schedule for IHSS 118.1 Monitored Natural Attenuation



IHSS 118.1 Schedule for Monitored Natural Attenuation		Task	Summary	Rolled Up Progress
Task		[Task bar]		
Progress		[Progress bar]		
Milestone		[Milestone diamond]		
			Rolled Up Task	
			Rolled Up Milestone	

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Appendix A
Alternative Analysis

APPENDIX A: ALTERNATIVE ANALYSIS

As described in the *RFCA Implementation Guidance Document* (IGD) (DOE, 1997), a two-step process was used to select the best alternative: (1) an initial screening to select the best alternatives, and (2) a comparative analysis of the alternatives. Both the screening and the comparative analysis are based on the three following criteria:

Effectiveness - Includes protectiveness of public health, workers, and the environment, ability to attain Applicable Relevant and Appropriate Requirements (ARARs), the level of treatment/containment, residual effect concerns, and the ability to maintain control on an interim basis.

Implementability - Includes the technical feasibility, availability of resources, and administrative feasibility.

Cost - Includes capital costs, operation and maintenance costs, and present worth analysis. Operation and maintenance costs are assumed to include sampling and analysis. Waste disposal costs aside from some transportation and sampling costs, are not included in the estimate. Costs are escalated five percent for outyears.

A.1 ALTERNATIVE SCREENING

As part of the alternative screening, thirteen technologies or groups of technologies were evaluated. Table A-1 lists the technologies evaluated in the screening process. Three technologies were selected for a final comparison. The other ten were eliminated primarily because of the:

- Inaccessibility of the DNAPL,
- Potential damage to the RFETS infrastructure,
- Technical impracticalities,
- Undeveloped or unproved effectiveness, and
- Partial removal of the DNAPL was not effective.

The three technologies selected for the comparative analysis of alternatives are:

- **No Interim Action** - Delay any remedial activity for IHSS 118.1 until a final remedy is selected.
- **Pump Carbon Tetrachloride** - Install a recovery well and pump system to collect the DNAPL
- **Monitored Natural Attenuation** - Demonstrate the natural reductive dehalogenation of the DNAPL.

A.2 DESCRIPTION OF ALTERNATIVES

A.2.1 Alternative 1 - No Interim Action

The no interim action alternative was defined as no action until the impediments to a final action have been removed. It does not preclude a final action at a later date when more building closures have occurred.

Table A-1 Screening of Alternatives for IHSS 118.1

Alternative	Description	Screening Results
1) No Interim Action	No interim action would be taken. This does not preclude a future or final action. The no interim action alternative supports the requirements of NEPA for selecting remedies.	Selected - Low cost, meets NEPA requirements for alternative analysis
2) Pump Carbon Tetrachloride	DNAPL would be removed with a product recovery pump(s) from wells screened above bedrock. Oil/water separation would be performed either in situ or ex situ.	Selected - Not disruptive to plant infrastructure and vital safety systems, relatively low cost, supports future remedial actions, only partial source removal is possible
3) Monitored Natural Attenuation	This alternative consists of demonstrating that there is a reduction of mass, toxicity, mobility, volume or concentration of contaminants through natural processes.	Selected - Cost effective, not disruptive to plant infrastructure, supports future remedial actions
4) Thermal Remediation Methods	Thermal methods include steam injection, resistive heating, thermal well technologies and other heating methodologies. Vapors would be captured and treated.	Screened Out - Potential damage to underground utilities, potential for short circuiting, some contamination is inaccessible, possible emissions, residual DNAPL would remain as a long-term source of contaminants
5) Excavation/Ex Situ Treatment	Complete removal of source material. Treatment would include thermal technologies, containerization, stabilization, solidification, bioremediation and other ex situ techniques.	Screened Out - Potential damage to underground utilities, buildings, and tanks, most of DNAPL is inaccessible
6) Soil Flushing	In this alternative, a solution would be pumped through the aquifer to extract or change the properties of the DNAPL.	Screened Out - Potentially high costs, could mobilize contaminants, residual DNAPL would remain as a long-term source of contaminants
7) Vapor Extraction	A vacuum would be applied to the subsurface to recover DNAPL as a vapor. Because the DNAPL is below the water table, the area would have to be dewatered to be effective.	Screened Out - DNAPL is below water table, some areas could be inaccessible even when combined with water removal, site is poorly suited to vapor extraction because the combination of the highly permeable alluvium, a shallow contaminant zone and limitations on excavation and drilling, residual DNAPL would remain as a long-term source of contaminants

Table A-1 Screening of Alternatives for IHSS 118.1 (Continued)

Alternative	Description	Screening Results
8) Pump and Treat with Multiple Phase Recovery	As opposed to pumping just DNAPL, water would be recovered with the DNAPL and separated out at the surface. The water would have to be treated before it could be returned to the environment.	Screened Out - High cost, recovery of DNAPL about the same as product removal alone, water treatment necessary, residual DNAPL would remain as a long-term source of contaminants
9) In Situ Vitrification	All of the soils in the area would be heated to their melting point. DNAPL would be driven off as a vapor and recovered with a fume hood.	Screened Out - High costs, process would damage tanks and utilities
10) In Situ Stabilization	In this alternative, stabilizing or solidifying binders would be injected into subsurface soils. Subsurface mixing would be required to effectively apply this technology.	Screened Out - High costs, damage would occur to utilities, some areas are inaccessible
11) In Situ Stripping	Wells would be installed with air spargers below the water table and the DNAPL layer. DNAPL would volatilize and the vapors would be recovered and treated.	Screened Out - High costs, possibility of uncontrolled emissions, some of the DNAPL might be inaccessible, residual DNAPL would remain as a long-term source of contaminants
12) Bioremediation	Microbes, nutrients, and/or oxidizers would be added to the groundwater to biodegrade contaminants.	Screened Out - Concentrations near source would be too toxic to directly affect source, effectiveness is unknown, residual DNAPL would remain as a long-term source of contaminants
13) Enhanced Attenuation	Oxidizers, catalysts, and reducing agents would be introduced to either the groundwater or the DNAPL layer to enhance or accelerate the chemical and biological breakdown of the contaminants. This technology could be combined with bioremediation.	Screened Out - effectiveness is unknown, possibility of toxic by-products, might damage subsurface utilities or structures, residual DNAPL would remain as a long-term source of contaminants

A.2.2 Alternative 2 - Pump Carbon Tetrachloride

This alternative consists of the installation of a collection and recovery system to pump DNAPL. The objective of this technology is to remove as much of the contaminant source as possible. Only DNAPL that could freely flow into the well would be recovered. DNAPL that is held in the soil by capillary pressure would not be recovered as discussed in Section 2.4. DNAPL below the T-9/T-10 Tanks or trapped by low permeability soils would also not be recovered.

A recovery well would be installed near Borings 02795 (Figure 2-3) about two to three feet below bedrock in the depression around Tanks T-9 and T-10. Additional recovery wells could be added to the system if needed. The lower segment of the recovery well would be comprised of blank pipe and serve as a free-product collection sump. The objective is to intercept the nonaqueous phase carbon tetrachloride layer to maximize the DNAPL to water ratio. It is assumed that the DNAPL, perched on top of bedrock in the tank excavations, would flow to the recovery well and accumulate as the fluid seeks the lowest point. A pneumatic pump to transfer recovered nonaqueous phase carbon tetrachloride to a container at the surface would be installed. Considering the likely sparse distribution of the nonaqueous phase carbon tetrachloride in the low permeability sediments, it is likely that this approach would recover a minor fraction of the total nonaqueous phase carbon tetrachloride present.

The free product would be pumped to a storage container, drum, or tank. Both the line and the container would have secondary containment. A high level alarm would keep the container from overflowing. Air to drive the pump would be taken from the overhead supplied air line. A slow recovery strategy would be employed to maximize the volume of carbon tetrachloride recovered and minimize the disturbance to the saturated hydrocarbon zone in the formation surrounding the well. It was assumed that the recovery system would operate for five years and that in the fifth year a closeout report would be written.

A.2.3 Alternative 3 - Monitored Natural Attenuation

Natural attenuation is the set of natural processes which reduce the mass toxicity, mobility, volume or concentration of contaminants in soil or groundwater through physical, chemical or biological action. The Office of Solid Waste and Emergency Response Directive 9200.4-17 defines "Monitored Natural Attenuation" as "...the reliance on Monitored Natural Attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remedial objectives within a time frame that is reasonable compared to that offered by other more active methods." This directive also states that "EPA does not view monitored natural attenuation as a 'no action' or 'walk-away' approach..." It should be noted that this alternative is not being evaluated as a final action and does not preclude a more effective treatment as a final action when the IHSS is more accessible.

The specific objectives of this alternative would be to determine through sampling, analysis, and evaluation whether natural conditions exist that are protective of surface water, i.e., that natural degradation of the DNAPL is occurring and that the DNAPL is contained in the bedrock depression.

A.3 COMPARATIVE ANALYSIS OF ALTERNATIVES

A.3.1 Alternative 1 - No Interim Action

Effectiveness:

DNAPL still would likely continue to be controlled through containment and degradation if no interim action was taken; however, it would not be monitored. A discussion of the natural attenuation processes that limit contaminant migration can be found in Section 2.5. Additionally, the same arguments concerning the effectiveness of natural attenuation made for Alternative 3 in Section A.3.3 also apply to the No Interim Action Alternative. No short-term or long-term environmental impacts are anticipated; however, due to a lack of monitoring, it will not be possible to verify this.

Implementability

There is no interim remedial action, so there are no immediate implementation problems.

Cost

There are no near-term cost impacts by not taking immediate action. Table A-2 presents a cost comparison of the alternatives.

Table A-2 Cost Comparison of IHSS 118.1 Alternatives

Costs	Alternatives		
	Alternative 1: No Interim Action	Alternative 2: Pump Carbon Tetrachloride	Alternative 3: Monitored Natural Attenuation
Capital Cost	\$0	\$504,400	\$245,700
Operation and Maintenance			
Year 1	\$0	\$192,000	\$118,000
Year 2	\$0	\$201,600	\$79,100
Year 3	\$0	\$211,700	\$48,500
Year 4	\$0	\$222,300	\$50,900
Year 5	\$0	\$263,200	\$108,600
Total Escalated Cost	\$0	\$1,595,200	\$650,800
Present Worth	\$0	\$1,442,100	\$616,400

(An escalation factor of five percent was used. For the present worth calculation, it was assumed that the escalation rate and the interest rate were identical.)

A.3.2 Alternative 2 - Pump Carbon Tetrachloride

Effectiveness:

The effectiveness of pumping the carbon tetrachloride was evaluated in terms of supporting the final remedial action objectives of protecting surface water and meeting the RFCA Action levels for subsurface soils, groundwater, and surface water. Pumping the DNAPL is ineffective for the following reasons:

1. Only a fraction of the DNAPL is recoverable,
2. The unrecoverable DNAPL still has the potential to contaminate millions of gallons of groundwater, regardless of how much is recovered,
3. On an interim basis, concentrations in the groundwater will likely stay the same or increase if DNAPL is removed (Pankow and Cherry, 1996, pp.496-497) and
4. Additional DNAPL sources in the area would also continue to contribute to groundwater concentrations.

The key interaction to consider is the equilibrium relationship between the DNAPL and the groundwater. Because there is excess DNAPL, groundwater concentrations are controlled by the solubility limits of the chemical contaminants. Basically, for water that is in contact with DNAPL, the contamination will tend toward saturation, i.e. it will tend towards the solubility limit as it comes into equilibrium. This relationship is not dependent on the volume of the DNAPL since at the interface the concentration in the water will tend towards saturation (solubility limit) regardless of volume of the DNAPL. On a larger scale the concentration is affected by diffusion, dispersion, the heterogeneous distribution of the DNAPL, the area of the DNAPL/water interface, reduced solubilities in multicomponent systems, mass transfer coefficients, and other physical and chemical parameters. Although this results in concentrations that are lower than saturated levels, these relationships are still not directly dependent on the mass or volume of the DNAPL present.

The removal of the DNAPL could increase mass transfer of chlorinated hydrocarbons from the DNAPL to the groundwater. The effective interfacial area between the DNAPL and groundwater could increase as water is pulled into the zone of DNAPL and comes in contact with the residual DNAPL tied up in the soil matrix. Because the mass transfer is a function of the interfacial area, an increase in interfacial area could result in a greater amount of mass moving into the water. More mass could also be transferred because there is more advective flow from pumping which would cause a greater volume of water to contact the DNAPL. At this site these factors could be negligible because the water is too stagnant even with the increase in flow from pumping, and it might continue to be primarily influenced by chemical equilibrium relationships.

The limitations of recovery are also dependent on the distribution of the DNAPL. The four states that the mass of carbon tetrachloride and other chlorinated hydrocarbons can reside in low permeability soils (Freeze and McWhorter, 1996) are:

1. DNAPL in the fractures,
2. Dissolved in the groundwater within fractures,
3. Dissolved in the groundwater in the matrix,
4. Sorbed on the solids in the matrix.

Figure 2-5 illustrates the distribution of DNAPL below the water table. This alternative would primarily address the DNAPL in the fractures. The effectiveness of recovering the DNAPL is dependent on the distribution of DNAPL. Because the DNAPL resides in an excavation that was backfilled with a variety

of materials, there are both low and high permeability materials in the zone of DNAPL contamination. Some DNAPL may not be hydraulically connected to DNAPL near an extraction well or materials with low permeability may hamper flow towards the well. This is because both low and high permeability materials were excavated for the tanks and were probably backfilled back into the excavation in a random manner. Evidence of this was found during the OU 9 investigation and IHSS 118.1 pre-remedial investigation. DNAPL could reside in fractures in the bedrock in which case it would most likely be below the screen interval for the recovery well. DNAPL could also be trapped above the water table.

Freeze and McWhorter (1996) estimated for tetrachloroethene in a low permeability soil (10^{-3} fracture porosity) that 48% of the mass would be distributed as DNAPL in the fractures with the remaining 52% sorbed on the soil or dissolved in groundwater. Of this 48%, only 50% (24% of the total mass of DNAPL) was estimated to be recoverable by a dual-phase system. For this alternative, the recovery rate is expected to be lower because of accessibility, permeability, and because the efficiency of a dual-phase recovery system is higher than a single-phase recovery system. It is difficult to find estimates of how much DNAPL is removed because generally it is not known exactly how much is present initially nor is it known how much remains after removal. At one documented chlorinated spill site, the recovery was about 30% (p. 228, Pankow and Cherry). For every gallon of DNAPL below the water table, a 30% recovery rate would still leave enough residual DNAPL to contaminate hundreds of millions of gallons of groundwater to RFCA Tier II levels.

Because of the inability of this alternative to effectively lower groundwater concentrations and the possibility that groundwater concentrations could increase, there could be negative short-term impacts to groundwater or surface water. Even though there is a reduction in the total mass and volume of the DNAPL, there is not a similar reduction in the mass, toxicity or mobility in the aqueous phase nor would this alternative maintain control of the contamination until a long-term solution could be implemented. Beneficial long-term effects would only be realized after significant depletion of the residual DNAPL had occurred. Air impacts and impacts to human health will also be minimal since it is a closed system. Impacts to flora and fauna, cumulative impacts, and impacts to cultural and historic resources are not anticipated because of location of the site and because of the limited scope of the response action.

Implementability

Unlike many of the alternatives considered during screening, it is possible to implement this alternative. The most prominent factor affecting implementation is accessibility. There are numerous utility lines, tanks, and buildings (see Figure 2-1) making a limited number of locations which a well can be placed. It is quite possible that the most suitable location lies beneath the T-9 and T-10 process waste tanks since the deepest part of the tank extraction is more likely to be closer to the center than the edges of the excavation. These tanks are currently part of a vital safety system and cannot easily be removed or replaced. Underground utilities crisscross this area and implementation is further complicated by a large number of overhead utilities and utilities that run on the ground surface.

Although implementation is severely hampered by accessibility, the equipment, resources, and the pumping technology are readily available. It is anticipated that off-site treatment and/or disposal of the DNAPL will also be available. Finally, based on the design, there are no permitting requirements or other administrative requirements that would hamper the implementation of this action.

Cost

A cost estimate for this alternative is in Table A-2. Of the three alternatives considered, pumping nonaqueous phase carbon tetrachloride was the most costly. The capital cost, the operation and maintenance cost, the total cost and the present worth of this alternative were the highest. The costs were

based on the assumption that waste would be disposed of through a DOE-complex wide program and that no costs for actual disposal would be incurred. Also, it was assumed that there would be no water treatment costs. If these assumptions are incorrect, then the cost of this alternative could increase significantly.

A.3.3 Alternative 3 - Monitored Natural Attenuation

Effectiveness:

Natural attenuation appears to be very effective in limiting the migration of contamination at IHSS 118.1 due to the physical, chemical and biological conditions at the site. The absence of carbon tetrachloride at SW-093 and in the foundation drains demonstrates that attenuation is probably effectively controlling DNAPL migration. As discussed in Section 2.0, the following factors contribute to the effectiveness of natural attenuation:

- The DNAPL is probably contained in the T-9/T-10 bedrock depression below groundwater flow streamlines. The stagnant water created in this depression limits mass transport of the carbon tetrachloride and creates conditions favorable for chemical reduction of the chlorinated solvents. The depression also constrains the areal extent of the DNAPL.
- Beneficial conditions exist for the reductive dechlorination. The presence of No. 2 Diesel probably acts as a substrate for microbes. Data collected to date suggests that degradation of the diesel is driving the reductive dechlorination of carbon tetrachloride and its byproducts.
- Low groundwater flow limits the migration of contamination and maintains stagnant conditions conducive to reductive dechlorination.

Natural attenuation will control and limit the migration of contaminants for all three alternatives; however, only this alternative will include monitoring of natural attenuation. The additional effectiveness that monitoring natural attenuation offers is that the process can be monitored to evaluate attenuation. Monitoring would be done to ensure the first objective of protecting surface water is met by sampling the groundwater before it reaches a surface water outfall and by ensuring that no migration of DNAPL is occurring. Benefits from this alternative that support a final action at IHSS 118.1 and closure of RFETS in general include:

- A determination whether natural attenuation is a viable alternative for a final action by itself or in combination with other actions,
- A means to monitor the site until a final remedy is possible,
- Additional analytical information that could be used as part of a basis of design for a final response,
- The information garnered could potentially be used for other DNAPL spill sites at RFETS,
- Groundwater information that can be used in evaluating and determining a response as part of the sitewide groundwater program, and
- A baseline can be established that will aid in closure and post-closure monitoring.

Monitored Natural Attenuation is expected to have little impact to human health and the environment since it essentially consists of well installation and sampling activities. Impacts to flora, fauna, archeological, and historical sites are not expected and can be avoided by offsetting the wells. Neither short-term nor long-term impacts are expected. The site is expected to remain a high usage industrial area through the project life for any monitoring activities in support of natural attenuation.

Implementability

Additional wells would be utilized both downgradient and upgradient. The location of these wells would be in more accessible areas than a recovery well for Alternative 2. Offsetting the wells would be less difficult because there is a greater degree of flexibility. Once all of the wells are installed, sampling will be straightforward and could be combined with the existing program for groundwater monitoring.

Cost

Although more costly than no interim action, Monitored Natural Attenuation was less costly than Alternative 2, Pump Carbon Tetrachloride. Table A-2 summarizes the costs for this alternative. Costs increase in the final year due to the preparation of an evaluation of natural attenuation. Operation and maintenance costs for this alternative consist primarily of sampling, analysis, reporting and project management costs.

A.3.4 Alternative Selection

Monitored Natural Attenuation was selected as the best measure for IHSS 118.1 at this time. Of the alternatives, it best met the objectives of protecting surface water and supporting a final response. It should be emphasized that Monitored Natural Attenuation is not a final response; the use of monitored natural attenuation does not preclude the utilization of a more effective technology at a later date when the IHSS is more accessible. The basis for this approach is twofold: first, the most effective technologies simply were not feasible at this time due to accessibility and secondly, the objective of the action is to protect groundwater and surface water. None of the alternatives screened and evaluated could effectively remove DNAPL in a manner that is protective of groundwater under current site conditions. Although the attenuation process would occur regardless of whether an action was taken, monitoring attenuation appears to be the best choice since it better supports a final action. Table A-3 is an overall comparison of the alternatives.

Monitored natural attenuation was selected over no interim action for the additional benefit of being able to monitor and evaluate the attenuation process. This will provide additional protection to surface water because samples will be taken prior to release to surface water. Furthermore, information garnered from studying the natural attenuation process and hydrogeology will be useful in determining a final response at IHSS 118.1 and possibly in other areas where chlorinated solvents exist at RFETS. Monitoring the attenuation process at the site will provide information on how residual contaminants in the soils and water can be mitigated through natural processes. Although the costs are higher, they are outweighed by the benefits of ensuring that surface water is protected, providing a baseline of evaluating attenuation across the site and providing needed data to support a final action.

Table A-3: Overall Comparison of Alternatives

Criteria	Alternatives		
	Alternative 1 - No Interim Action	Alternative 2 - Pump Carbon Tetrachloride	Alternative 3 - Monitored Natural Attenuation
Effectiveness	Low - Natural attenuation would continue to reduce the toxicity and mobility of contaminants although it would not be monitored.	Low - Approximately 5-30% of the DNAPL can be removed. Remaining DNAPL will continue to contaminate groundwater and could increase groundwater concentration.	Medium - Based on preliminary data, containment of the contaminants and the natural attenuation processes are limiting contaminant migration.
Implementability	High - This alternative does not require any action to implement.	Low - Accessibility limits the installation of a system. More effort is required the install because it is more complex.	High - Only wells would be installed and there is more flexibility in their placement. Once the wells are installed operations would consist only of sampling.
Cost	Cost = \$0 Since no interim action would be taken, no costs would be incurred for this alternative.	Cost = \$1,595,200 This is the most costly of three alternatives because it is more resource intensive.	Cost = \$650,800 This alternative costs about \$800,000 less than what it costs to pump the DNAPL.

Appendix B

Calculation of Mass Flux and Mass Flow Rate at IHSS 118.1

Date: May 27, 1998

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File Name: flux2.txt

Title: IHSS 118.1: Calculation of the Mass Flux of Carbon Tetrachloride

Calculations by C. D. Cowdery

Checked By: Hopi Salomon

Signature C. D. Cowdery Date 7/28/98

Signature Hopi Salomon Date 7/28/98

IHSS 118.1: Calculation of the Mass Flux And Mass Flow Rate of Carbon Tetrachloride

Objective: To calculate the mass flow rate and mass flux of carbon tetrachloride at various points downgradient and downstream of IHSS 118.1.

Methodology: The mass flow rate is calculated by multiplying the aqueous volumetric flow rate times the dissolved concentration of carbon tetrachloride. The volumetric flowrate for groundwater is calculated in by using Darcy's Law (Fetter, 1988):

$$Q = KA\left(\frac{h_a - h_b}{L}\right)$$

where,

Q = Volumetric Flow Rate of the Water

K = Hydraulic Conductivity of the Porous Media

A = Cross-Sectional Area

h_a = Hydraulic Head at Point A

h_b = Hydraulic Head at Point B

L = Distance Between Point A and Point B

The mass flux is calculated by dividing the mass flow rate by the cross-sectional area.

Assumptions:

1) It is assumed that the flow through the claystone is negligible and that only flow through the Rocky Flats alluvium has significant enough contaminants to evaluate. It was assumed that the flow of contaminants was not retarded, i.e., that advective flow and mass flow were equivalent. This assumption is based on the low organic carbon content of the alluvium and the assumption that the impact of clay sorption would be negligible.

2) The first calculation is across the area where DNAPL is present at IHSS 118.1. The hydraulic conductivity in the Industrial area is 2.10×10^{-4} cm/sec (4.13×10^{-4} feet/min.) from Table G-7 of the Hydrogeologic Characterization Report for Rocky Flats Environmental Technology Site (EG&G, 1995). The saturated thickness is taken at well 5197 since this is probably not in the depression from the T-9/T-10 excavation. Assume that contaminated flow is as wide as the area where free product has been detected or about 45 feet. The gradient is taken between water table contours of 5980' and 5970' because these two contours bound the area of where DNAPL was found span the site and generally along the flow direction (see attached map). Ground water data was used from the 1/28/97 water level measurements. The average contaminant concentration was found by averaging all of the values from wells with

DNAPL or 792,500 ug/l.

3) The calculation of the mass flux on the north side of the IHSS was made using the same hydraulic conductivity of 2.10×10^{-4} cm/sec (4.13×10^{-4} feet/min.), cross-sectional area and gradient referenced above. The effect of dispersion was assumed to be negligible. The gradient was developed by taking the difference in elevation between Well 5397 (5977.48') and the footing drain (5948.58') dividing by the distance between the two (80').

4) The flowrate from the footing drain based on the report titled *A Description of Rocky Flats Footing Drains* (EG&G, 1992) and is 1 gpm or less. As a worst case, 1 gpm was used.

Calculations:

Across IHSS 118.1:

Saturated Thickness - For Well 5197

$$(\text{Depth to Bedrock}) - (\text{Depth to Groundwater}) = 13.6' - 6.71' = 6.89'$$

Cross-Sectional Area - $45' \times 6.89' = 310.05$ sq ft

Gradient - From the potentiometric map of the water table surface (see attached):

$$dh/dL = 10'/124.4' = 8.04 \times 10^{-2}$$

Flow rate -

$$\begin{aligned} Q &= (4.13 \times 10^{-4} \text{ feet/min.})(310 \text{ sq ft})(8.04 \times 10^{-2}) \\ &= 1.03 \times 10^{-2} \text{ ft}^3/\text{min} \\ &= 7.70 \times 10^{-2} \text{ gal/min} \\ &= 0.292 \text{ l/min} \end{aligned}$$

The mass flowrate of carbon tetrachloride is

$$\begin{aligned} M &= 0.292 \text{ l/min} \times 792,500 \text{ ug/l} \\ &= 0.231 \text{ grams/min} \end{aligned}$$

The mass flux is 7.45×10^{-4} gram/min-ft²

Downgradient of IHSS 118.1:

Saturated Thickness - For Well 5197

$$(\text{Depth to Bedrock}) - (\text{Depth to Groundwater}) = 13.6' - 6.71' = 6.89'$$

$$\text{Cross-Sectional Area} - 45' \times 6.89' = 310.05 \text{ sq ft}$$

Gradient -

$$dh/dL = 8.04 \times 10^{-2}$$

The same gradient was used for both the mass flow rate across the IHSS as downgradient of the IHSS.

Flow rate -

$$\begin{aligned} Q &= (4.13 \times 10^{-4} \text{ feet/min.})(310 \text{ sq ft})(8.04 \times 10^{-2}) \\ &= 1.03 \times 10^{-2} \text{ ft}^3/\text{min} \\ &= 7.70 \times 10^{-2} \text{ gal/min} \\ &= 0.292 \text{ l/min} \end{aligned}$$

The mass flowrate of carbon tetrachloride is

$$\begin{aligned} M &= 0.292 \text{ l/min} \times 680,000 \text{ ug/l} \\ &= 0.1986 \text{ grams/min} \end{aligned}$$

The mass flux is $6.404 \times 10^{-4} \text{ gram/min-ft}^2$

771 Footing Drain:

Flow rate -

$$\begin{aligned} Q &= 1 \text{ gal/min} \\ &= 3.78 \text{ l/min} \end{aligned}$$

The mass flowrate of carbon tetrachloride is

$$\begin{aligned} M &= 3.78 \text{ l/min} \times 43 \text{ ug/l} \\ &= 1.63 \times 10^{-4} \text{ grams/min} \\ &= 85 \text{ grams per year} \end{aligned}$$

The mass flux could not be calculated because the cross-sectional area is not known.

SW-093:

No carbon tetrachloride has been detected in SW-093.

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Title: IHSS 118.1: Calculation of the Mass Flux of Carbon Tetrachloride

The average flow rate between 1994 and 1997 is 0.20 cubic feet per second or 90 gallons per minute. The flow rates are as follows:

Average of MEAN CFS	YEAR				Average of
MONTH	1994	1995	1996	1997	All Values
1		0.078	0.043	0.052	
2		0.096	0.059	0.112	
3	0.166	0.098	0.132	0.128	
4	0.443	0.844	0.168	0.760	
5	0.219	1.191	0.409	0.189	
6	0.091	0.596	0.077	0.137	
7	0.037	0.046	0.055	0.094	
8	0.052	0.029	0.037	0.429	
9	0.029	0.091	0.228	0.155	
10	0.067	0.045	0.069	0.339	
11	0.119	0.062	0.074	0.296	
12	0.042	0.042	0.061	0.221	
Annual Average	0.133	0.289	0.121	0.243	0.200

Results:

Location	Liquid Flow Rate (gallons/min)	Concentration (ug/liter)	Mass Flow Rate (grams/min)	Mass Flux (grams/min-ft ²)
Across IHSS 118.1	0.077	792,500 (Average)	0.231	7.45×10^{-4}
North Side of IHSS 118.1	0.077	680,000	0.1986	6.40×10^{-4}
771 Footing Drain	1.0	43	1.63×10^{-4}	N/A
SW-093	90	Not Detected	Not Detected	Not Detected

References:

EG&G, 1992, A Description of Rocky Flats Foundation Drains, EG&G Rocky Flats, Golden, Colorado, November, p. 8.

EG&G, 1995, *Hydrogeologic Characterization Report for the Rocky Flats Environmental Technology Site, Volume II of the Sitewide Geoscience Characterization Report*, EG&G Rocky Flats, Golden, Colorado, Appendix G.

Fetter, C. W., 1988, *Applied Hydrogeology*, 2nd ed., New York, New York, MacMillan Publishing Company, P. 77.

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Title: IHSS 118.1: Calculation of the Mass Flux of Carbon Tetrachloride

Northeast Flow

10 foot drop over 130 feet

To the north towards gradient - $10'/130' = 0.0769$

$Q = (4.13 \times 10^{-4} \text{ feet/min.})(310.05 \text{ sq ft})(0.0769)$

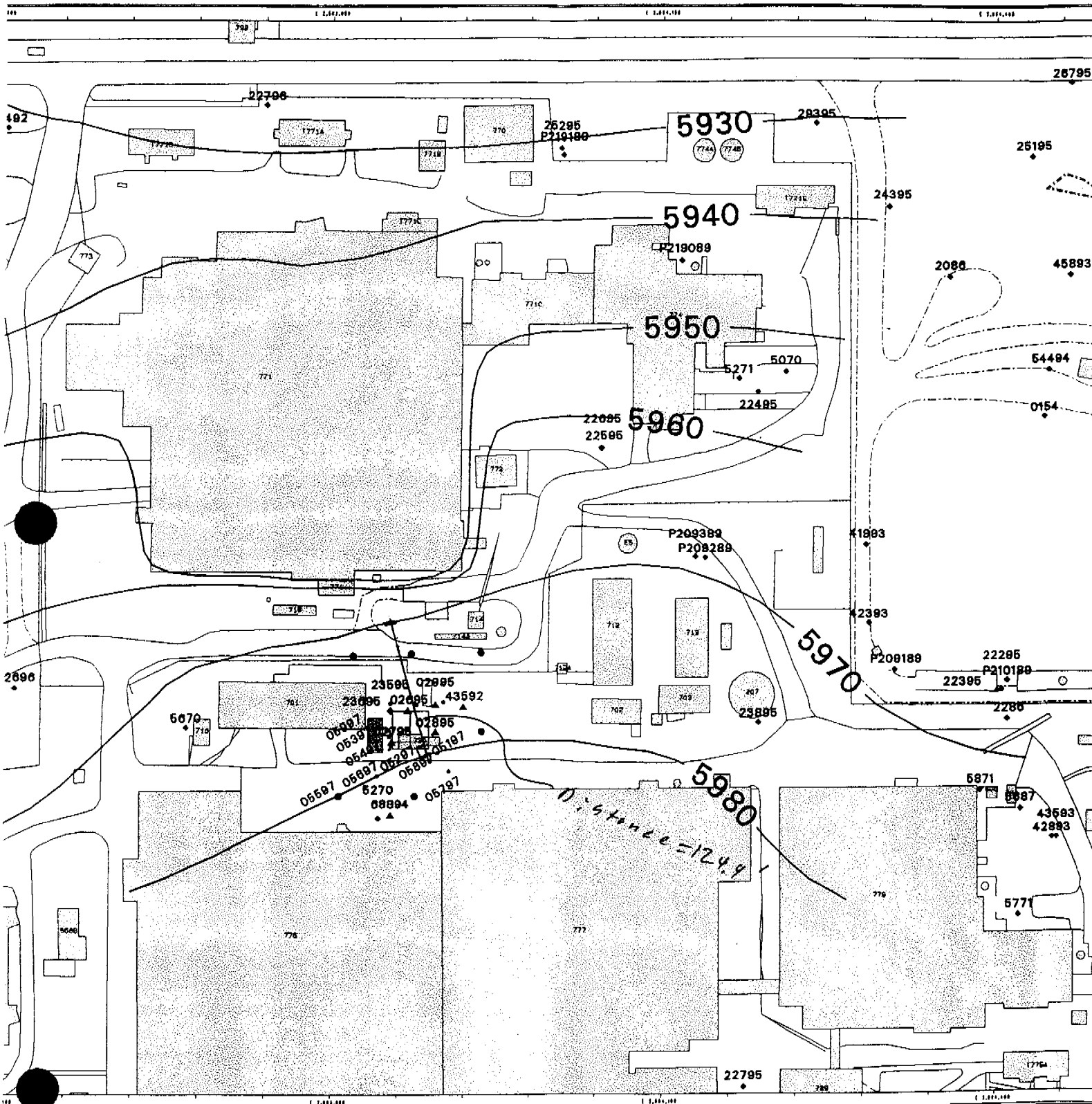
$= 9.85 \times 10^{-3} \text{ ft}^3/\text{min}$

$= 0.0736 \text{ gpm}$

$= 0.279 \text{ l/min}$

Flow Rate

$1300 \text{ ug/l} \times 0.279 \text{ l/min} = 3.63 \times 10^{-4} \text{ g/min.}$



Response to Colorado Department of Public Health and the Environment Comments on the Final Technical Memorandum No. 1, Monitored Natural Attenuation of IHSS 118.1

1. Section 2.3.1 - Groundwater Samples (page 14) - The discussion of groundwater samples states that many organic compounds may be present below the high detection levels needed to dilute the primary contaminants into detection range. Explain how degradation products can be identified accurately if this is the case.

Response: *Based on a review of data from past remedial investigations at Rocky Flats Environmental Technology Site, concentrations of the primary degradation products of carbon tetrachloride have been high enough in many samples to accurately detect and quantify. The degradation products include chloroform, methylene chloride, carbon disulfide, hexachloroethane, perchloroethene, and hexachlorobutadiene. There might be some additional reactions that are occurring that are not detectable near the source. There are special laboratory methods for dealing with this; however, since most of expected degradation products have been detected plus some unexpected ones, these special analytical methods will not be pursued at this time.*

Samples taken around the process waste tanks T-9 and T-10 potentially have droplets of free phase carbon tetrachloride in them. Downgradient samples from the proposed wells will not be in contact with free-phase carbon tetrachloride. If degradation is occurring in the alluvium, then these samples could contain the degradation products from those reactions at detectable levels.

This statement in the IHSS 118.1 Technical Memorandum is primarily referencing the absence of chloromethane since it is the intermediate between methylene chloride and methane. The absence of chloromethane could also be because it is more conducive to biological degradation that it is converted to methane relatively rapidly and therefore is not in measurable quantities or because it is so volatile, it is being lost prior to or during analysis. Finally it could be that chloromethane is not being formed. The degradation of carbon tetrachloride is stopping at methylene chloride. By measuring methane and downgradient chloromethane, it might be possible to explain its absence.

The statement in the text will be modified to read as follows:

"As a result, these compounds may be present at concentrations below these elevated detection limits; however, as shown in Table 2-5, many potential degradation products and semivolatiles were detected above the elevated detection limits despite this masking effect."

2. In addition to Figure 2-5, a local top of bedrock map or a north-south cross section would be useful to illustrate the excavation area in the direction of groundwater flow.

Response: *The extent of the excavation and the direction of ground water flow have been added to Figure 2-1. At this time there is no information on the top of bedrock contour between IHSS 118.1 and Building 771. The core logs from installation of the proposed monitoring wells north of IHSS 118.1 should provide the information to make a north-south cross-section that extends north to Building 771.*

3. Section 2.4 (page 22) - "Containment" is not included in the list of natural attenuation processes in Section 2.5 and they should not be lumped together in the last paragraph of Section 2.4. The third to last sentence in that paragraph should be modified to state, "...the low concentrations in the drain suggest

that contaminant migration is being severely limited by containment within the tank excavation and through attenuation processes such as containment, dilution or and degradation."

Response: *This sentence has been modified as requested. However as a matter of explanation, what we are calling containment is due in part to dilution and in part due to reduced mobility due to the lower permeability of the clay that was put back into the tank excavation. It could potentially be considered natural attenuation based on the definition in EPA guidance (OSWER Directive 9200.4-17). This definition states "The natural attenuation processes that are at work in such a remediation approach include a variety of physical, chemical, or biological processes that, under favorable conditions, acts without human intervention to reduce the mass, toxicity, mobility, volume or concentrations of contaminants in soil or groundwater." The containment of the carbon tetrachloride in the bedrock depression is a physical process that acts without human intervention to reduce both the mobility and the concentration of contaminants in the groundwater. It is not specifically listed in this guidance, but it appears to fit the definition.*

4. Table 2-10 (page 22) - Neither the text nor this table explains how the Liquid Flow Rate across IHSS 118.1 was determined. The mass flow rate across IHSS 118.1 appears to have been calculated from the liquid flow rate of the dissolved plume across the IHSS and the average concentration of the contained portion of the plume. This would produce a misleading mass flow rate since a flow rate determined by gradient and estimated hydraulic conductivity would apply to the dissolved plume concentration near the top of the excavation and not to the contained contaminant concentration measured near the bottom. The derivation of and justification for the factors used in the Table 2-10 calculations should be explained in the text. It would improve the understanding of this problem to measure the flow rates at different levels in the excavation.

Response: *This is a really good point. A five page appendix that documents the basis for the total mass flux calculations will be added to the technical memorandum. The text will be modified as follows:*

"The flow rate across IHSS 118.1 was calculated using a gradient and the saturated thickness in the alluvium. Because the concentration is based on ground water that is from both the alluvium and water contained in the bedrock depression, the concentrations are probably much higher than they would be for the alluvium alone. For this reason the reduction in mass flow rate between the IHSS and the foundation drain may be due more to the containment of contaminated water in the bedrock depression than due to degradation. The calculation of mass flow rates are presented in Appendix B of this document."

It would improve the understanding of what is occurring to measure the flow rates at different levels in the excavation; however, at this time, it would not directly assist in meeting the objectives of this project. In terms of protection of surface water and evaluating a final approach for the site, the horizontal movement of contaminants between the IHSS and surface water outfalls is more important to understand. Since we have information on hydraulic conductivity in the alluvium and the claystone, and we know the approximate conductivity in the alluvium and that the flow at the bottom of the excavation is likely to be very low, then additional discrete flow measurements should only give the shape of the flow profile. Furthermore, since these methods are not extremely accurate and the measurements could only be made over an approximate fifteen foot interval, the information would likely be more qualitative than quantitative. Once the data is collected, if it appears that these measurements are crucial to ensuring that surface water is protected or it plays an important role in a final remedial approach, then these measurements should be reconsidered.

5. Section 2.5 (page 24) - Containment of the DNAPL at the source is described in the text as the physical factor having by far the greatest effect on contaminant migration. Containment, however, should be clearly distinguished from natural attenuation processes. It is not included in the list at the beginning of Section 2.5 or in EPA directives. Important information differentiating the effect of containment from degradation could be gained by collecting discrete samples at several vertical locations in the two wells intended to be reinstalled in the excavation.

Response: *(See response to Comment 3.) As discussed in Comment 3, although containment is not specifically listed in the EPA directive, it appears to fit the definition of natural attenuation in the directive. The same directive does stress that the Environmental Protection Agency prefers attenuation processes that degrade the contaminants. Although discrete samples at vertical locations could possibly differentiate between reduced concentration due to degradation versus containment, it would be more practical and protective to first determine what the concentrations are between the IHSS and the foundation drains and what is actually in the foundation drain. In the technical memorandum the priority was put on protecting surface water.*

Although evidence of natural attenuation was found around the tanks, there are no wells between the IHSS and the building foundation to evaluate downgradient flow. Additionally, information is needed on whether significant dilution is occurring in the foundation drain itself. In designing a monitoring program for natural attenuation, consideration was given to establishing the direction and concentration of downgradient concentrations and where attenuation process are occurring. By installing wells in the downgradient alluvium, we will get an idea of what the concentrations are in the alluvium above the IHSS since natural attenuation probably won't have a significant effect on contaminant concentrations. The groundwater will probably not have reductive dechlorination processes occurring because it is likely that there are no sources of petroleum hydrocarbon for bacteria to subsist on and because it is a thinner saturated thickness that is likely to have more exposure to air and hence a higher redox potential. If the model based on the data taken so far is correct, chemical degradation should be limited to the area around the process tanks. The distance between the down-gradient wells and the bedrock excavation is only about 40 feet, and since water in this area is less stagnant, i.e. the residence time is lower and there is not as great a residence time for degradation. Furthermore, due to the short distance, not much dilution or dispersion is expected to take place.

There are a number of advantages to sampling in the alluvium downgradient of the IHSS as opposed to trying to take discrete samples in the alluvium above IHSS:

- 1. The problem with cross contaminating samples due to the presence of free phase DNAPL will also be avoided. Cross contamination due to mixing problems will be avoided.*
- 2. The downstream samples will show what is moving away from the IHSS towards surface water outfalls rather than what is near the IHSS.*
- 3. The inaccuracies due to discrete sampling methods will be avoided; however, this will be offset by any effects that occur between the IHSS and the downgradient monitoring wells.*
- 4. The contaminant concentrations relative to flow direction can be evaluated.*

While attending a short course at the University of Waterloo, the opportunity was taken to discuss this with Dr. John Cherry who had just done a presentation on discrete vertical sampling. He agreed that discrete samples at IHSS 118.1 didn't make sense because there is vertical flow and the aquifer is not very thick.

6. Section 3.2 (page 26) When included in the anticipated SAP (or IM/IRA modification), the data

quality objectives should be stated as data needs rather than as sampling processes. The sampling processes can be included in the text as a means to accomplish the DQOs. The listed DQOs could be restated as:

- To monitor contaminant containment
- To monitor natural attenuation control of contaminant migration
- To ensure protection of surface water
- To establish background concentrations of key parameters
- To determine groundwater flow direction

other possible DQOs include:

- To identify and quantify other sources of carbon tetrachloride in the industrial area
- To determine the rate of contaminant degradation
- To establish the vertical segregation of contaminant concentrations within the plume. If collection of vertical flow and chemical information is accepted as important then they should be added to the DQO section.

Response: *The sampling and analysis needs will be rewritten to match the comments as follows:*

- "
- To monitor contaminant containment
 - To monitor natural attenuation control of contaminant migration
 - To ensure protection of surface water
 - To establish background concentrations of key parameters
 - To determine groundwater flow direction"

The Data Quality Objectives in the SAP will be developed using the EPA seven-step method; however, they should be similar to those listed above. Additionally, if enough information is available, the contamination degradation rates will be determined. Identifying other sources of contamination is very important but this scope is a component of the Industrial Area Characterization that will be conducted in future years. As previously discussed, characterizing the vertical segregation of the contaminant concentrations is not planned, but could be evaluated if the current sampling approach does not establish how much containment is occurring. Revisions to the SAP could be necessary once the data is collected to address this and other possible sampling needs.

7. Table 3-1 The anticipated SAP (or IM/IRA) should specify the analytical methods to be used.

Response: The SAP will delineate the analytical method for each analyte. Most of the analyses will be done using EPA methods; however some of the analytes such as hydrogen in water or methane will need to use specialized analytical methods.

Response to Environmental Protection Agency Comments

EPA Comment in the letter from Mr. Tim Rehder to Mr. Steve Slaten (REF: 8EPR-F):

"As discussed in our meeting of April 28, the document could be improved by more clearly stating the objectives of the proposed action which are listed in section 3.1, page 26. The primary objective should probably be: Demonstrate that the IHSS 118.1 plume does not impact surface water and will not in the future. An additional or corollary objective should also be included: Delineate the plume extent. EPA also suggests that the Building 771 footing drain should be sampled several more times to ensure that the plume is not migrating through this pathway, as was suggested in the document based on an historical sampling event."

Response: *The primary objective will be changed per your comment to:*

"Demonstrate that the IHSS 118.1 plume does not impact surface water and will not in the future."

Although the planned IHSS 118.1 groundwater monitoring might define the plume extent, it is not likely since there are three potential sources outside of IHSS 118.1 that could be sources of carbon tetrachloride. These sources include a spill West of Building 701, a potential spill that is under Building 776, and a potential source beneath and/or around Building 779. Ideally, the plume will be defined by downgradient sampling, but the proximity of these additional sources and historical sampling (see volatile organic compound plume maps in the annual reports for Rocky Flats Cleanup Agreement groundwater monitoring program) indicate defining the plume to the east and west might not be possible and that contamination from other sources could have merged with the IHSS 118.1 plume. Currently the preferred method of determining plume extent is to evaluate the industrial area as a whole instead of just investigating individual IHSSs. Two programs outside of the IHSS 118.1 project will further characterize plume extent in this area, the RFCA Groundwater Monitoring Program and upcoming Industrial Area Characterization. For these reasons, defining the plume extent would be better served by the RFETS sampling program that addresses sources outside of IHSS 118.1.

The sampling of the 771 Footing Drain has been added to the sampling program; however, the drain lines from the 771 Footing Drain have been redirected and they will have to be relocated to determine if sampling is possible. At this time it appears, that the 771 Footing Drain could be connected to a line north of Building 774. There are some lines that run into Bowman's Pond north of 774 but it is unknown whether these are the same lines. In any case, there is the possibility that the line might be diluted or contaminated by the other lines from Buildings 771 and 774 that run into it. If the water from around Building 774 or the east side of Building 771 is part of the flow at the outfall, then carbon tetrachloride might be present from sources outside of IHSS 118.1.

Figure 2-3
Cutaway View Of IHSS 118.1

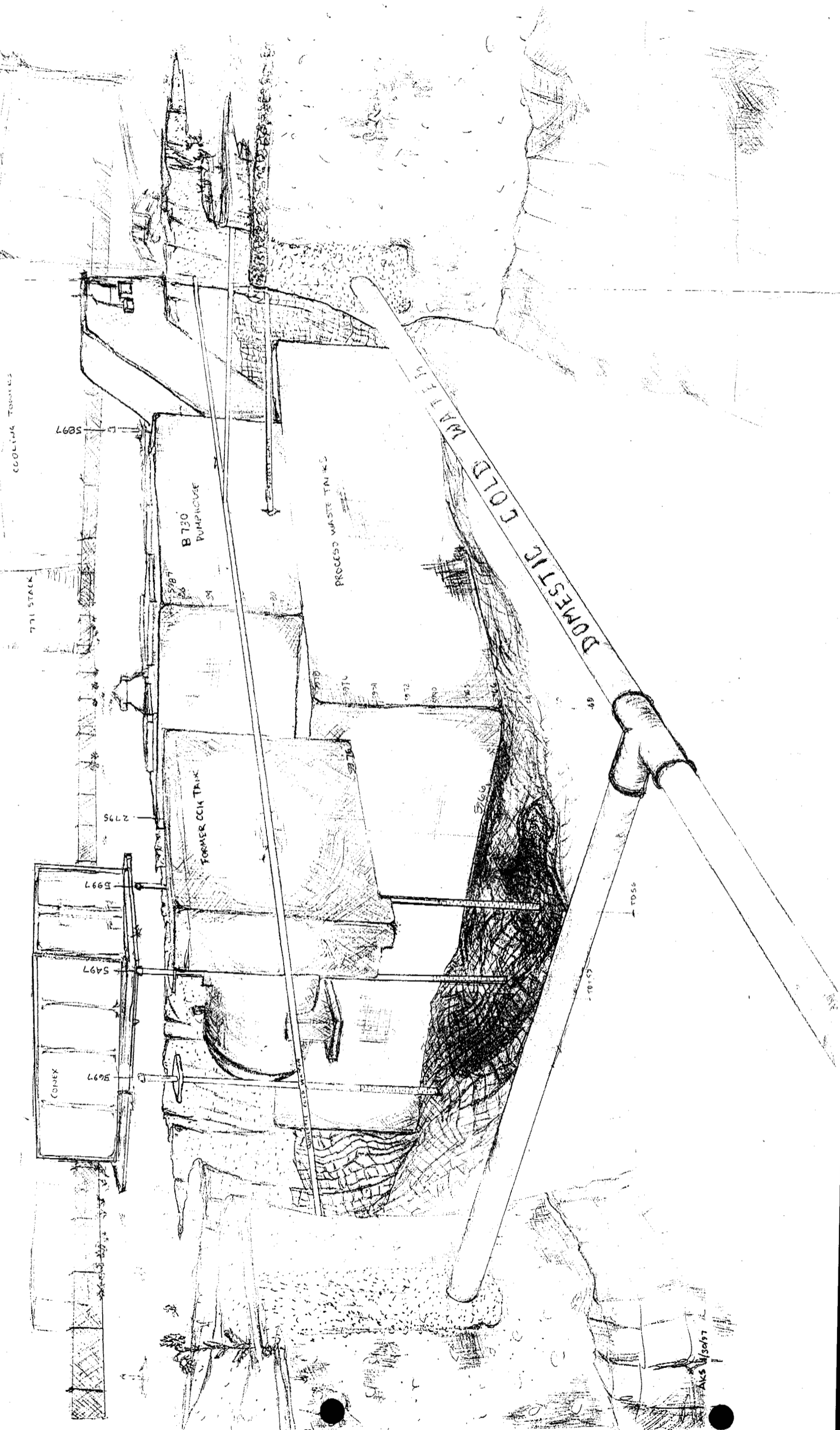


Figure 2-5
IHSS 118.1 Generalized Hydrogeologic Cross Section

